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ABSTRACT

This document of conference proceedings is divided into five sections. The first, STS (Science Technology and Society) Studies, contains five papers: (1) "Scientific Discourse and Public Policy" (Jane C. Webb; George R. Webb; Charolette Webb); (2) "An Answer to Neil Postman's 'Technopoly'" (David K. Nations); (3) "Reflections on the Theory and Practice of Constructive Technology Assessment" (Jesse Tatum); (4) "Total Quality Management as An Ethics Issue Mediated by Technology Transfer in Unsolicited Sociotechnical Interventions" (Ely A. Dorsey) and (5) "'Silent Spring' The Myth of Two Cultures" (Doris Z. Fleisher). The second part is on women in science and technology, and also contains five papers: (1) "Ordinary and Extraordinary Women in Science" (Darlene S. Richardson; Connie J. Sutton); (2) "Women and Technology: Feminist Perspectives" (Linda Condron); (3) "Why Constructivist Classroom Practice Can Increase Participation of Women and People of Color in Science" (Barbara J. Reeves; Cheryl Ney); (4) "From Hostile Exclusion to Friendly Inclusion: Transforming the College Science Classroom" (Darlene S. Richardson; Maureen McHugh); and (5) a preliminary report on the NSF project discussed in the previous paper (Sue V. Rosser). The third section, Bioethics, Health, and Medicine, contains two sections: (1) "Breast Implants and the Challenge of An Informed Public" (R. Eugene Mellican); and (2) "Bioethics Event-based Future Worksheet" (Richard G. Dawson). The fourth section looks at STS in the Nonindustrialized World. The three articles are: (1) "Sustainable Development: Some Interpretations, Implications, and Uses" (Subodh Wagle); (2) "Transcending Efficiency's Dilemma: A View from the Coadaptationist Position" (Craig R. Duennen); and (3) "Urban Sustainability in an Industrializing Country Context: The Case of China" (John Byrne; Young-Doo Wang, Bo Shen; Congfang Wang, Ziuguo Li). The fifth and final section is devoted to education. The part on K-12 contains 18 articles. The section on higher education contains 10 articles. The part on research has four articles. (DK)

PROCEEDINGS OF THE EIGHTH NATIONAL TECHNOLOGICAL LITERACY CONFERENCE

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Edited by
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with a foreword by
JAMES J. MURPHY

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FOREWORD

When I was reading the abstracts and proposals and preparing the session schedules for the Eighth National Technological Literacy Conference, one of my regrets was that it would not be possible for me to attend all of the presentations and discussions that promised to be so interesting and provocative. Now, reading these Proceedings mitigates that regret somewhat, for they give me a truly representative sample of the meeting and allow me a glimpse of some of the ideas and arguments I missed because of not being abie to solve my problem of only being at one place at any given time. I hope that you will be as delighted as I to see this collection that the editors have so ably gathered and polished to convey an image, not only of what went on in Arlington in January of 1993, but also of the range and depth of issues and projects that engage those who are currently active in the pursuit of STS explorations.

The number of papers having to do with STS in the classroom signifies not only the deep involvement of NASTS members in teaching and learning, but also the current stage of maturation of STS educational approaches. There are more courses, programs, materials than ever before, but beyond that, now is an appropriate time to report on successes, progress, and problems. If you are more concerned with issues than pedagogy, don't pass over the contents grouped under the educational headings. STS deals with real issues, even in the academic curriculum.

One reputation of (and a frequent rap on) STS studies is that they are carried out by those critics who have an unrelievedly pessimistic view of modern technology. I do not think this is a proper view of the field, nor is it borne out by the contents of these Proceedings. STS scholars are indeed critics of technology, however, like theater critics their legitimate role is a constructive one and will result most often in a cadenced judgement rather than a complete pan or an absolute rave. Even when a scholar's assessment on the general directions of developing technologies, or the inequities in the control of technological development is decidedly pessimistic, good STS thinkers (NASTS members) are not so naive as to group all technology simple-mindedly into one monolithic category. A good STS work may be presented as a strongly held conclusion, far to one side of center on the issues in question. Judge it not as a polemic, but in terms of the strength of the argument and its supporting evidence and in terms of how well it provokes and promotes discussion. The issues themselves, and the development of a capable, aware and engaged citizenry demand more involvement in discussions of science, technology, and society interactions. Look through this collection for contributions which illuminate, diverge and convince. Do not look for pronouncements which forestall debate.

It is the nature of the Technological Literacy Conference to promote discussion. All accepted papers and sessions are structured to stimulate participant involvement. The reader of the Proceedings misses the flavor of this interaction, which is, at ground level, what NASTS is all about. Conversations continue in the meeting rooms and out into the hallways after sessions. While there is considerable rediscovery and rehashing, there is

also discovery and inspiration in plenty. The new insights triggered by discussions after papers and conversations in the halls will emerge at the next conference just as some ideas you are about to read had their origins in the exchanges among NASTS people at the previous year's meeting. Perhaps you, who join us now as reader, will join us next January as a conference participant. Please consider this an invitation.

James J. Murphy
President of NASTS, 1993-94
New Rochelle, NY
September, 1993

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SCIENTIFIC DISCOURSE AND PUBLIC POLICY: THE CONTROVERSY OVER THE EXPERIMENTAL INTRODUCTION INTO VIRGINIA'S YORK RIVER OF *CRASSOSTREA GIGAS*

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On Tuesday, April 28, 1992, the Virginia Marine Resources Commission voted 6 to 2 to allow an overboard experiment[1] in Virginia's York River with a sterile triploid oyster, *Crassostrea gigas,* to proceed (Minutes, VMRC, 4/28/92). The months preceding the vote had been characterized by intense and frequently heated lobbying, both for and against the experiment. The overboard experiment was not intended to be an <u>introduction</u> of a non-native species in the wild; however, the newspapers, several of the interest groups, and the general public appeared to think that a general introduction was either planned or would occur. The experiment had been proposed by a consortium of the Virginia Institute of Marine Science and Rutgers University's Haskin Shellfish Research Laboratory, and it appears to have been the consensus of the public that the Commission would take a stand against approval of the experiment (Latané, L. 1992). At the April 28 Commission meeting, there were a number of speakers arguing for and against the proposal. Among the speakers was Dr. Dennis Taylor, the Director of VIMS, who spoke in support of the experiment. Shortly after the approval of the overboard experiment by the Commission, Dr. Taylor publicly withdrew his support of the experiment.

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[1] An overboard experiment is one conducted in the natural environment of the river rather than in the laboratory.

The focus of this paper is the encounter between a citizen board, in this case the Virginia Marine Resources Commission, and the scientific community, and the manner in which scientific discourse affected a public policy decision. Specifically, the changing positions of Dr. Taylor before and after the vote seriously weakened the confidence of the citizen board in the scientific community, a confidence that, to judge by comments by the Commissioners, was already in some disrepair (Latané, 1992). A close examination of this case raises questions concerning the manner in which scientists interact with public policy bodies, and the extent to which the implicit authority of scientific discourse may be used to manipulate public policy decisions.

We will begin by presenting the background material necessary to understand the situation in Virginia and the parties in the discussion; we will move on to the events of the Commission meeting itself; we will analyze the responses of the Commissioners and the public statements; and we will offer some possible suggestions. It is to be hoped that the presentation of this case will allow some discussion to occur.

Background: the Players in the Case

In Virginia, the Marine Resources Commission (VMRC) is the regulatory body created by the Legislature to deal with fisheries and habitat matters. The present Commission, a citizen board of eight individuals appointed by the Governor, is chaired by Commissioner William Pruitt who is the chief executive officer of the Marine Resources Commission staff, some 160 individuals who are engineers, fisheries and habitat personnel, Marine Police, and support people. The Commissioner is himself appointed by the Governor and he reports to the Virginia Secretary of Natural Resources. The VMRC is advised in both fisheries and habitat matters by the Virginia Institute of Marine Science (VIMS) which has a legislative mandate to support the Commission. VIMS, an arm of the College of William and Mary, has a staff of scientists and is directed by an academic scientist, Dr. Dennis Taylor, who replaced Dr. Frank Perkins in 1991.

In this particular situation, a third group played a role. The Governor's Blue Ribbon Oyster Panel, an ad hoc body appointed by Governor Wilder in early 1992, evaluated the radical decline in the oyster population and made recommendations concerning future actions by the Commonwealth of Virginia. The impact of this

committee of scientists, regulators, and representatives of all the people having an interest or an economic stake in the oyster and the oyster industry will be discussed later in the presentation.

Statement of the problem.

We begin by laying out the problem, which has social, economic, political and ecological ramifications.

The heart of the issue addressed by this paper is the fact that the oyster population in the Chesapeake Bay has plunged precipitously over the past 30 years. In the 1986/87 season, 342,784 bushels of oysters went to market, with an average of 85 boats of watermen harvesting per day. By the 1990/91 season, the standing stocks were estimated at 78,420, an estimate that is now considered overly optimistic, and an average of 31 boats per day brought to market only 43,406 bushels (Blue Ribbon Oyster Panel Report. Data collected by staff of VMRC). The decline is blamed on various factors, from overharvesting, or pollution, to the appearance and rapid spread of two diseases, dermo, (*Perkinsus marinus*,) and MSX, *Haplosporidium nelsoni* .[2] The merits of the arguments concerning the causes of the decline are not under discussion for the purposes of this paper. We simply make the point that the decline has occurred and that it has had a substantial impact on the people participating in the fishery as well on on the ecosystem of the Chesapeake Bay and its estuaries in Virginia.

The groups affected by the fishery have, of course, been participants in the discussions that have gone on concerning the decline of the oyster population, as have environmental groups such as the Chesapeake Bay Foundation and the Environmental Defense Fund. The affected groups include the watermen, who constitute a recognizable and cohesive cultural unit in Virginia; the packers, who buy the oysters from the water, pack it, and sell it to the markets; and the economic sector in general, from the marketers to the suppliers of fishing equipment, boats, *et cetera*. (Webb, G. R. and J. C. Webb, 1984). Finally, it is important not to overlook the importance of the oyster to the ecology of the Chesapeake Bay as a whole. As a

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[2]MSX was an acronym for multinucleated sphere, unknown, a term employed when scientists first began to work on causes of death in the oyster population. MSX has become the popular designation for Haplosporidium nelsoni.

filter feeder, the oyster is an important member of the benthic community and makes a major contribution to the water quality of the Bay. A hundred years ago, oysters were so numerous that they "could have filtered the Bay's entire water volume in 3 to 5 days" (Blankenship, 1992). Today's oyster population is so small that it has a negligible impact on either water quality or the ecosystem.

Discussions over the oyster decline and suggestions for remedies have been going on in Virginia for more than a decade. One possible solution that has been and continues to be the source of both interest and controversy is the introduction into Virginia waters of the non-native species of oyster *C. gigas,* sometimes known as the Japanese oyster. This oyster, by virtue of its robust qualities and vigorous reproductive characteristics, has been introduced all over the world in response to the international decline in various native oysters. A Pacific oyster, *C. gigas* flourishes in Australia, in France, and on the west coast of the United States, among other places. It has proven itself resistant to most strains of the diseases affecting those populations.

Under its legislative mandate to support the Marine Resources Commission, the Virginia Institute of Marine Science (VIMS) took the main role in designing and conducting experiments with *C. gigas* to determine whether this oyster would in fact be resistant to the diseases raging in the Chesapeake Bay. Under the leadership of Roger Mann, research in the VIMS laboratory supported the conclusion that the *gigas* is resistant to dermo; however, most scientists conclude that the second disease, MSX, has never been successfully introduced in the laboratory setting.[3] Since no experiment had succeeded in challenging *C. gigas* with MSX in the laboratory, it was concluded by Mann and others that only an overboard experiment would allow an evaluation of the oyster's ability to survive an MSX challenge. Without that piece of data, the VIMS staff felt it could not evaluate the introduction of a non-native species into Virginia waters; such an evaluation would be essential should the Marine Resources Commission (VMRC) eventually decide to proceed with an introduction of the *gigas.*[4]

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[3]The single experiment, conducted at Deal Island, in which it was said that a successful laboratory experiment had occurred, has never been published in a peer reviewed journal, although its existence has been referred to in public discussions concerning *C. gigas.*

[4]While it appears from his statements before the Commission that Dr. Taylor assumed the Director of the VIMS has the authority to allow or prohibit the

Introduction of the non-native species may be regarded, as indeed it was by environmental groups and officials of the State of Maryland, as bringing with it all of the dangers attendant on introducing new species into an uncontrolled situation. Popular rhetoric in discussions over *C. gigas* included frequent references to rabbits in Australia, nutria in Louisiana, hydrilla in American waterways, and the replacement of the native Australian Sydney Rock oyster, *Saccostrea commercialis* , by the imported *gigas*. Those who supported the idea of the introduction, who initially were chiefly the packers, argued that all the evidence indicated that the waters of Virginia would not be sufficiently hospitable to allow the *C. gigas* population to explode, as was the case in Australia. The proponents pointed out that *gigas* flourishes in an intertidal environment where the oyster rocks are actually out of the water for part of the tidal cycle; such locations are very few in Virginia. If, however, the oyster were to survive an MSX challenge, it would perhaps allow the oyster population to expand sufficiently to address the economic needs of watermen, packers, and the markets, and, of even more importance, it would fill a painfully empty ecological niche that is of crucial significance, not only to the food chain but also to the water quality of the Virginia Bay.

Contributors to the debate leading up to the VMRC decision and its aftermath which we intend to analyze were the scientists, represented by the VIMS/Rutgers group headed by Drs. Roger Mann and Standish Allen; scientific administrators, at first Dr. Frank Perkins, Director of VIMS and then his replacement, Dr. Dennis Taylor; the watermen and packers; and the Governor's Blue Ribbon Oyster Panel. The debate itself cannot be understood without acknowledging the fierce opposition to the introduction of *C. gigas* to Virginia waters by officials in the State of Maryland,[5] and the feeling held by many that it is just a question of time before the Federal government removes from the separate states the right to introduce

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introduction of non-native species, the Code of Virginia section 28.1-183.2 prohibits the introduction of non-native fish or shellfish unless the introduction "has received written permission from the Commission." In this particular situation, Commissioner Pruitt made the decision to allow the full Commission to pass on the VIMS/Rutgers experiment, technically viewed as an introduction.

[5]". . . you should withhold permission to conduct in-water experiments or to introduce c. gigas into the Bay." Letter to VMRC Commissioners from Torrey C. Brown, MD, Secretary of Natural Resources of the State of Maryland, April 24, 1992.

new species. It is of interest and relevant to this discussion to note that the oyster industry in Maryland remains in fairly good health, and that Maryland and other areas of the U.S. have been able to fill the needs of Virginia packers for oysters.

The Blue Ribbon Panel

As we have mentioned, mounting political pressure from the watermen and the packers had led to the appointment by Governor Douglas Wilder in 1991 of a Blue Ribbon Oyster Panel, which took testimony from a wide spectrum of interested parties and presented to the Commission a series of interrelated recommendations for restoring the oyster population and the industry itself. The Panel, which included all of the constituencies interested in and affected by the oyster problem, was supported by the staff of the Marine Resources Commission, several of whom participated in the discussions. Three of the Commissioners were among the people appointed to the Panel, as were several scientists and two scientists emeritus from VIMS. The meetings continued for nine months; one of the specific recommendations included in what came to be dubbed The Holton Plan was the <u>introduction</u> into Virginia waters of *C. gigas*. The Blue Ribbon Committee did not recommend merely an overboard experiment with a small population of sterile oysters; it recommended an overboard introduction in specific areas. The Blue Ribbon Panel's report went to the Marine Resources Commission in late 1991, where it was accepted in principle and was sent to the Fisheries staff, supposedly to be reconciled with internal concerns and presented to the full Commission for action in time for the 1993 oyster season.

The Scientific Experiment: VIMS and Rutgers

During the months that the Blue Ribbon Panel was meeting and gathering testimony, Roger Mann was working not only on the VIMS second and third generation of laboratory-bred *C. gigas*, but he began a cooperative exploration with Standish Allen of Rutgers on the possibility of using triploid *C. gigas* from the Haskin lab. Allen and Mann thought that the use of the triploid oysters would effectively respond to the fear of an exploding *C. gigas* population which would overrun the local *C. virginica*, since the triploid oysters were almost all sterile, and those gametes that were produced were not viable.

The Blue Ribbon Panel's support for an overboard introduction in tandem with the cooperative efforts of VIMS and Rutgers to design and put in place 300 triploid individuals as part of a formal MSX challenge led VIMS to ask for a place on the April agenda of the regular monthly meeting of the Marine Resources Commission in order to receive permission to proceed with the experiment. While the early work had been done while VIMS was under the leadership of Dr. Frank Perkins, in 1991 Dr. Dennis Taylor had taken over as Director of VIMS. Dr. Taylor was the speaker on behalf of the VIMS/Rutgers experiment who was scheduled to address the Marine Resources Commission meeting.

The Commission Meeting of April 28, 1992.

While it was generally thought, even by Commission members themselves, that the Commissioners came to the meeting of the 28th intending to vote down the *gigas* experiment, a survey of the Commissioners conducted for the purposes of this study reveals a slightly different story. Of the eight Commissioners, two entered the meeting FOR the experiment; three were AGAINST it; three viewed themselves as NEUTRAL. Of the two Commissioners who were FOR the experiment, only one had made her position publicly known; the other Commissioner had not made up his mind until shortly before the meeting, and had not revealed his changed position.

The Blue Ribbon Panel's overboard recommendation had already been received by the Commission; in view of the difference between the Commissioners' perceptions of what their fellows thought and what they actually did think about the *gigas* experiment, it seems likely that the Blue Ribbon Panel's recommendation had made a difference. This is born out by a survey of the Commissioners. When asked about the importance of the Panel's recommendation, five Commissioners said that the Blue Ribbon's position had influenced their decision; only three said it had not. Two of the three who were not influenced by the Panel were those who voted NO on the experiment.

Of the people who gave formal position papers on the overboard experiment, four are of particular interest. The Chesapeake Bay Foundation representative, Dr. William Goldsboro, spoke against the experiment. Dr. Peter L. DeFur, Senior Scientist of the Environmental Defense Fund, spoke briefly in favor of the experiment. In his presentation, Dr. DeFur made it clear that he

understood the difference between an introduction and the proposed experiment, and that he was convinced the triploid oysters were not going to reproduce. By far the longest presentation was that of Dr. Taylor of VIMS, who pointed out that experimentation such as that proposed with the triploid *gigas* was necessary in order for VIMS to fulfill its legislated mandate. Dr. Taylor was followed by Dr. Mann, who said that both Dr. Perkins in his tenure as VIMS Director and Dr. Taylor supported the experiment. Dr. Mann urged the Commission to take due account of the weight of the recommendations of the two distinguished senior scientist-administrators, and to support the experiment.

A survey of the Commissioners showed that Dr. Taylor's presentation was "very important" to five Members; "somewhat important" to two (both of those being the Members who arrived in favor of the experiment); and "not important to one. " Dr. Mann's presentation was regarded as "very important" to two; "somewhat important" to three; and "not important" to three. The difference between Dr. Taylor and Dr. Mann in their impact on the Commissioners' decision-making process leads one to conclude that Dr. Taylor's standing as a senior scientist-administrator was important to this citizen board setting public policy (material that follows is based on Minutes of the Commission Meeting augmented by portions of the untranscribed tapes).

Following the presentations, the Commission members discussed the matter themselves. That discussion, while available only on tape, is very interesting to consider because only this discussion was viewed by all the Commissioners as having been "very imp rtant" to their deliberations. The discussion was opened by the Commissioner who had declared herself in favor of the experiment before the meeting. She said that while she knew she was "going to go down by myself," she felt the issue was sufficiently important for her to make a public declaration of the reasons for her position. She separated the question into its several parts: the economic, political, scientific, and ecological components. She was interrupted by the second Commissioner who had come into the meeting with a decision to support the experiment.

One of the key points of the continuing discussion was a letter in the briefing packets of the Commissioners from Dr. Allen. Directed to Gail Critchlow, Chief of the Delaware Bureau of Shellfisheries, it was dated March 22, and it dealt directly with the problem raised by

several of the Commissioners, the problem of spawning. In the quoted portion of the letter, Dr. Allen says "triploid *C. gigas* do produce some gametes. . . . But no viable progeny have ever been obtained from crossing TRIPLOID males with TRIPLOID female *C. gigas*. In addition, triploid females are even more reproductively incompetent than males." In his letter, Allen supports his argument by reference to his own work (Allen and Downing, 1990). There was some anger over the issues of gametogensis and reproduction expressed by at least one Commissioner, who said that the trouble with scientists is that they are like lawyers: "They answer the question you asked, instead of telling you what you want to know." Following this exchange, Dr. Taylor said, "I have advocated this experiment strictly on the basis that there is a consensus that there is valuable information that can be gained and the risks are minimal. . . . I am an advocate for the scientific position." He also indicated that he had not seen the Allen letter.

The public conversation among the Commissioners eventually was concluded by a motion being made and seconded to support the overboard experiment, with the Commission wording and rewording the motion several times until it very clearly spelled out their approval of an experiment, not an introduction. The Commissioner called for the vote, and the experiment was approved 6 to 2.[6] The intensity of the debate and the moral burden felt by the group is indicated by the fact that at the time of the vote, one Commissioner said to a second, "God help us." At the close of the meeting, Commissioner Pruitt said to one Commissioner that he had told Elizabeth Haskell, Secretary for Natural Resources, that if there had been a tie vote at the meeting, he would have broken the vote in favor of the experiment. Legally, however, despite the Commission's vote, the experiment would wait on the Commissioner: his signing off is required in Virginia in order for non-natives to be introduced into Virginia's waters.

Reaction to the approval of the overboard experiment was quick in coming. In Maryland, locus of a considerable amount of the opposition, a spokesman for Maryland's Department of Natural Resources said Maryland was "investigating all possible options. . .

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[6]When the Commissioners were interviewed for the purposes of this paper, six remembered voting Aye and two remembered voting Nay. One who remembered voting Aye actually voted Nay; while one who remembered voting Aye actually voted Nay. From the Questionnaire circulated at the Commission meeting of December 22, 1992.

It's a very important issue to us for obvious reasons." Paul Perra, program director of the interstate fisheries management for the Atlantic States Marine Fisheries said, "There's talk of a lawsuit in Maryland. . . .I don't know if we have any federal laws on this or not. It's unclear" ("Foreign oyster study," 1992). Other East Coast oyster producing states also indicated concern. J. Claiborne Jones, assistant director of the tri-state Chesapeake Bay Commission, said that there have been "very few examples of an introduction of a non-native species that proved not to cause difficulties" ("Bay Oyster Experiment," 1992). Proponents of the experiment were elated. Packers who had faced long periods of inactivity believed strongly that this oyster held the only hope for the future of the industry in Virginia.

The argument over the Commission's decision was to be short-lived, however; in early June, the test oysters at Rutgers died, the result of an oversight by the laboratory assistants left in charge of the tanks while scientists were out of town at a national fisheries meeting; it would be a full year before another generation of triploid oysters would be available. More important to the Commissioners, however, was a change in position by Dr. Taylor. On June 1st, Taylor indicated he would delay the experiment until he reviewed a "new study" that "says they" [the triploid *gigas*] pose no threat to the Chesapeake Bay. The study referred to appears to be the work of Dr. Allen, on which the letter read into the record of the April VRMC meeting was based. Interestingly, from the point of view of the two scientists most closely involved, Drs. Allen and Mann, this study was conclusive in its support for the position that the triploid oysters would not give rise to offspring. It should be noted that Dr. Mann was not a participant in the work of the study itself. On June 16, Dr. Taylor formally reversed himself, writing to William A. Pruitt that "there is insufficient data in hand" to support the conclusion that the oysters cannot reproduce. This letter was not made public initially, but in a relatively short time, the newspapers discovered what had happen.

On July 3, 1992, the Richmond Times Dispatch printed an article headlined "Taylor criticized on oyster test shift." Describing Taylor's changed position, the article argues that "Taylor's about-face on what is probably the most contentious and important resource decision made by the commission in two years does not sit well" with the two Commissioners the paper could reach by telephone. Both Commissioners described anger at what they felt was a "flip-flop,"

and one said, "I think people ought not to take stands unless they are sure in their own minds that they know what is going on" (Latané. 1992). While Taylor had told the Commission that "We have done everything humanly possible to close off the possibilities" that the triploid oysters might reproduce, the second Commissioner said, "He has raised questions he didn't present to us in May."

Reaction of the Commission as a whole was an expression of anger. The Commissioners viewed themselves as having over and over again experienced difficulty eliciting useful information from the scientists charged with providing them with the data on which to base public policy decisions. They regarded this difficulty as a characteristic of the relationship between public policy making bodies and the scientific community; their frustration had been expressed fairly openly over the years. When they were asked how they had felt when they learned that Dr. Taylor had changed his position, five said they had been "very surprised," with two of them suggesting an additional category called "pissed off." One was only "surprised," and the two who were "not surprised," both of whom had been Aye voters on the experiment, both thought that the Director of VIMS had responded to pressure from the State of Maryland, to which he had close ties. Several of the Commissioners said that they had concluded that Dr. Taylor had felt free to argue for the overboard experiment only because he was confident that the Commission itself was sufficiently negative so that it would vote No; and this confidence was reasonable since only one Commissioner had been identified as supportive of the experiment before the April meeting and several others had indicated serious reservations in previous public discussions. Thus, those Commissioners regarded the change of Taylor's position as a political act having nothing to do with the scientific question at hand. When asked why the VIMS Director might undertake such a stance, a Commissioner said that Taylor needed to "keep his staff happy. He supports Mann, and Mann is happy. We vote no, and Mann is mad at us, not at Taylor" (Webb, J.C., 1992. Private communication).

Conclusion

This case presents more than the usual difficulties encountered when scientists enter into formal discourse with public policy bodies. The first, and the one most common, is the nature of the vocabulary; it is not our purpose to discuss that problem. The second, a classic problem, is the inability of scientists to take a position that

something is a "sure thing." The scientific model requires the view that probabilities govern the natural world. The public policy makers who are citizens do not make judgements from this position, and the inability of the scientific community to give them a familiar yardstick leaves them frustrated, uncertain, and sometimes renders them impotent to make judgements on critical issues that take the scientific position properly into account. This problem is one that could be rectified, if scientists were only able to find a way to speak in the language of the citizen board. A suggestion, made by one of the Commissioners to staff members at VIMS several years ago, was that VIMS' recommendations to the VMRC ought to come with a 1 to 10 scale; something that everyone understands from watching the Olympics. Unfortunately, the 1 to 10 scale is one that is not easily translated into scientific discourse, but surely it is not impossible for such an easily understood referent to be introduced.

The third problem, and the focus of this paper, is the special responsibility born by the scientific administrator, who must speak for disciplines that are not his own. In this case, Taylor more than once referred to himself before the Commission at the April 28th hearing as "a humble plant physiologist." At this same meeting, however, he seemed quite sure of himself; he said "this is the one opportunity that you have had scientifically in the past 30 years to get at the heart of the matter of this disease that you are trying to deal with in the oysters; and it's likely to be the only opportunity that you're going to have" (Transcription of the meeting, 1992). Based on Dr. Taylor's testimony alone, it is not possible to fault the Commissioners for believing that the Director of VIMS bowed to political pressure. Yet such conclusions seriously undermine the scientific community's best efforts to advise citizen boards. If such public policy making boards are to rely on scientists--and it is highly desirable that they do so--then the scientific community must avoid even the appearance of political complicity.

Public policy making bodies operate in a political world. It is a characteristic of the political system that people frequently camouflage their real purposes in order to confound the opposition. Scientists representing their institutions before public bodies must take serious cognizance of the fact that the people before whom they testify will be, based on their political experience, suspicious of anything that looks duplicitous; even the appearance of such a thing makes for increasing difficulty in the interaction between scientists and public policy bodies.

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AN ANSWER TO NEIL POSTMAN'S TECHNOPOLY

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"Something has happened in America that is strange and dangerous, and there is only a dull and even stupid awareness of what it is....I call it Technopoly." (Postman, 1992:20)

In Neil Postman's terms, Technolopy is a state of society in which tools and techniques dominate everything else.

"Technopoly...consists in the deification of technology, which means that the culture seeks its authorization in technology, finds its satisfactions in technology, and takes its orders from technology." (Postman, 1992:71)

Postman believes that in our rush to embrace technology we have given up almost everything that gives meaning and direction to human life. This leaves Americans with a relatively empty human existence. He describes this existence as "a life of skills, technical expertise and the ecstasy of consumption." (Postman, 1992:179)

What is it, exactly, that Postman thinks we have lost? In Postman's view, human life is given meaning and direction by "narratives of transcendent origin and power." We no longer have a "story of human history that gives meaning to the past, explains the present, and provides guidance for the future." Every society needs such a narrative because its "principles help a culture to organize its institutions, to develop ideals, and to find authority for its actions." (Postman, 1992:172) Equally important is an associated "repertoire of significant national, religious, and mythological symbols." (Postman, 1992:178)

Postman's problem with America today is that "the growth of Technopoly has overwhelmed earlier, more meaningful stories." This has been accompanied by "the trivialization of the symbols that express, support and dramatize the story." (Postman, 1992:173) For Postman, without such stories and symbols "it is certain that no culture can flourish." (Postman, 1992:172) Thus, America today is in a bad state and the dominance of society by technology is largely to blame.

According to Postman, the way to fight against the dominance of technology is to "always keep close to your heart the narratives and symbols that once made the United States the hope of the world." (Postman, 1992:182) (He mentions the Statue of Liberty and the works of Thomas Jefferson.) The way to free our children from the dominance of technology is to teach every school subject "as history." (Postman, 1992:190)

I shall return to Postman's admittedly sketchy solution later. First, I want to talk about Postman's analysis of the problem of technology and society.

Postman blames the problems of Technopoly on people who see human problems in purely technical terms. He blames those who promote new technologies without proper regard for their societal effects. And he blames all of us for not keeping our technical tools under control. In all of this, Postman provides an important critique. The book is marred, however, by language that makes technology itself the chief villain.

In his description, technologies fight each other for dominance: "the alphabet attacking ideographic writing, the printing press attacking the illuminated manuscript, the photograph attacking the art of painting, television attacking the printed word." (Postman, 1992:16)

When one of these warring technologies wins out, it imposes its ideology on society. "A new technology...changes everything....Television gave a new coloration to every political campaign, to every home, to every school, to every church, to every industry." (Postman, 1992:18) Over and over the reader of Postman's book finds that tools and not humans are the actors.

Here are two other examples of this pervasive language:

"Doctors do not merely use technologies, but are used by them." (Postman, 1992:105)

"The computer redefines humans...." (Postman, 1992:111)

Postman does a good job of alerting us to some of the most basic questions raised by the role of technology in modern society. He does not, however, do a good job of preparing his readers to solve these problems. He writes as if technologies are living things with wills of their own, things that act, have intentions, and can tyrannize human beings. First of all, this promotes an unnecessary sense of helplessness that discourages the reader from becoming a problem solver. Second, it is simply inaccurate.

Technologies do not act; men and women do. Television does not orient us to instant gratification; we gratify ourselves by watching television. Experts don't mislead us unless we abdicate our decision-making roles. Most of us who live in a technological culture have had moments of feeling diminished before a complex machine. But it is the choices we make and the values we employ that determine what role technology will have in society and in our individual lives.

If we are going to tackle the problems Postman describes, we need to begin with this recognition of our ultimate responsibility and, thus, our ability to do something about the problems of technology in society. More basically, if we are going to do something about the problems that come with advancing technology, we need to know _why_ Americans are allowing technology to be put to inhumane uses and to interfere with the making of meaningful lives.

A similar comment could be made about a number of other recent books that blame science or technology for the problems of modern society. (For example, _Brave Modern World_ by Jean Chesneaux, _Voltaire's Bastards_ by John Saul and _Understanding the Present_ by Bryan Appleyard.)

The kind of analysis I find missing from _Technopoly_ is found in a closely reasoned book called _The Dilemma of Modernity_ by philosopher Lawrence Cahoone.

Cahoone details the development of what most Western people today would call the modern view of things. In order to find the root of our modern problems, Cahoone goes back to the 1600s and to Enlightenment thinkers like Descartes. Starting at this early date, he documents the development of a philosophy that divides the universe into a private world of consciousness and a public world of matter. He argues that this philosophy, taken to its logical conclusion, denies the existence of anything _but_ private consciousness and public matter.

What advantages did the Enlightenment find in such a worldview? In the 1600s, medieval culture was a barrier to scientific, technical, and political progress. Enlightenment modernism served to dissolve this barrier. It gave progressive Europeans a basis on which to declare medieval custom, religion, and everything else that stood in their way to be nothing but myth. This view became dominant as medievalism was overcome, and as medieval culture was overcome, scientific and political progress sprinted ahead.

Today, this worldview pervades Western society. Health care, social work, academics, politics, law, and religion operate within this philosophical basis. We have ample

evidence of consequences of this philosophy that Enlightenment thinkers did not foresee. One of these unforeseen outcomes is a threat to modernism itself and to the progress it has brought.

When the Enlightenment worldview is carried to its natural conclusion, religion, custom, and morality are classified as private pathologies. Communities, nations, and families are seen only as physical, biological, and economic entities. There are no universal principles of right and wrong. Men and women are urged to see themselves as random collections of atoms, the product of purposeless evolution in a meaningless universe. Anything that claims to have other than psychological or material value is classified as myth and superstition and ruled out for serious consideration. In the extreme, then, our heritage from the Enlightenment leaves us without ethics, without a meaning or direction for human life, and stripped of human dignity.

Because of this consequence, Cahoone finds this modern worldview in need of repair. He values the democracy, individualism, and humanism that have come with modern progress. But he also joins a long list of thinkers from Edmund Burke to Michael Oakeshott and Richard John Neuhaus in pointing out that this complete clearing away of cultural values removes some of the most essential supports of the free society. Enlightenment philosophy, without modification, produces a cultural vacuum and this cultural vacuum invites a totalitarian system.

This is the point at which Cahoone provides a clue to the actual source of Postman's Technopoly. If he is right, the root of the problems Postman describes is not the advance of technology but our acceptance of a worldview that is not adequate to control this advance.

This, then, is part of my answer to Postman. We are not overpowered by our technologies, as his language suggests. Instead, we have accepted a particular, anti-cultural ideology which leaves us no basis for the dominion we should have over our tools. Without cultural objects, such as shared values and a sense of human dignity, we find ourselves unable to turn technology to humane purposes and to make meaningful human lives in an increasingly technological world. Thus, it is not modern technology but Enlightenment ideology that has brought us to the Technopoly Postman describes.

Of course, the founders of the Enlightenment had no intention of depriving human life of meaning and direction. In place of medieval culture they actually hoped to establish a new morality on a purely naturalistic basis. This experiment, however, has not proved equal to the challenges posed by

political, scientific, and technological progress. As a result, modern society is politically, scientifically, and technologically advanced but culturally retarded. Instead of moral beings, men and women see themselves as nothing more than individuals, meeting their psychological needs, within an ever-varying economic system.

I see this modern ideology exemplified, for example, in classrooms where a student succeeds, not as part of a community of learners but as an independent atom that wins grades by individual effort, often at the expense of others.

Such classrooms mirror our modern society, which is too poor in shared values to bring technologies under human control and turn them to humane purposes. Thus, we have individuals and corporations that are willing to pollute their neighborhoods in order to keep their financial profits as high as possible.

We also see the effect of this modern ideology in the lack of human dignity which leads citizens to go on mindlessly consuming every new technology industry can produce. A value of Cahoone's study is that it reveals at the core of Enlightenment modernism a fundamental opposition to everything that supports modern man's beleaguered sense of individual self-worth.

Postman and Cahoone agree, then, that a loss of that which gives meaning and direction to human life is a major problem of modern society. Postman writes as if technological advance is causing this loss. I believe, instead, that it is our prior acceptance of a faulty ideology that is causing a loss of meaning and direction and a loss of our ability to bring technology under human control.

Finally, let's return to Postman's solution. Recall that in his view we lack "narratives of transcendent origin and power" and a "repertoire of significant national, religious, and mythological symbols." In my view, Postman's solution is as flawed as his analysis of the problem.

Postman's description of the missing cultural objects as narratives and symbols comes directly out of the Enlightenment ideology that is causing our problems. If we accept the division of the universe into public matter and private consciousness, then shared values and a sense of human dignity are nothing more than narratives and symbols. If that is all they are, they can be easily dismissed as so much myth and superstition.

Our need is not for more myth and superstition but for cultural objects that have as much reality as matter or private

consciousness. Fairness, concern for each other, concern for the environment, human dignity -- if these are going to give meaning and direction to human life they must be among our realities and not reduced to mere private fantasy or selfish genes. We need a modified modern worldview that makes room for such realities. This is not a call for a revolution but for a necessary evolution of our Enlightenment heritage.

Where do we start? We might begin with the fact that many mathematicians already believe there is a non-material reality behind their symbols. Numbers exist, they are not someone's private fantasy; neither are they material objects. (Davis, 1981) In a similar way we should be able to make room in our worldview for cultural objects, like values, which offend the Enlightenment ideology in somewhat the same way that numbers do.

We might also begin by assuring each other that even though we are giving up pure nominalism, our critical faculties can continue to operate. We can still decide that although fairness exists, species are no more than populations of similar individuals.

One of the most strenuous objections to this modification is that making room for non-material realities will open the door to domination by myth and superstition. Surely this fear is exaggerated. The Enlightenment threw the baby out with the bathwater. I believe that we can find a way to bring the baby back in and leave the bathwater where it belongs. How else are we going to bring advancing technology under proper human control? How else are we going to overcome Technopoly?

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REFLECTIONS ON THE THEORY AND PRACTICE OF CONSTRUCTIVE TECHNOLOGY ASSESSMENT

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It is one of the fundamental contentions of philosophy of science since Thomas Kuhn (1962) and of the more recent literature on the "social construction" of science and technology (Bloor, 1976; Latour, 1987; Bijker, et al., 1987) that modern patterns of science and technology are not simply inherent in nature. These patterns do not, it is broadly suggested, emerge of necessity, but bear the indelible imprint of human agency, emerging at least in part as a product of the inevitable selectivity of human attention[1]. Modern patterns, furthermore, are not obviously the culmination or even the most advanced product of any fixed "method" or notion of "progress" (e.g., Kuhn, 1962; Feyerabend, 1975, 1978; Marx, 1987). Science and technology, it is argued, are "underdetermined" (Latour, 1987) by external realities and thus are always also contingent on human actions and/or choices.

This paper will begin with the contention that more vigorous attention to the developmental path of science and technology, specifically in the form of "constructive technology assessment" (CTA) efforts, is necessitated in a democratic system by recognition of the contingent nature of science and technology. The focus in this argument will be on the exercise of power implicit in the political construction of technology and on the often subtle, even unrecognized, nature of that exercise of power. After developing this argument, specific examples will be used to suggest means by which CTA efforts might be furthered and to indicate where they might most critically be needed.

Political Construction of Technology

As the contingent or underdetermined nature of science and technology has become increasingly accepted in recent years, much has been made of practical and theoretical evidence for the "social construction" of science and technology. In many cases, this "social" construction may seem an unexceptional process. The precise configuration of the modern bicycle, for example, may be of relatively little concern even if "there is nothing 'natural' or logically necessary about [the process of] closure" that brought us the air tire and eliminated the old "high-wheelers" as Pinch and Bijker (1987) argue. Speed apparently became the ultimate design criterion in this case, and "It could be argued that speed is not the most important characteristic of the bicycle or that existing cycle races were not appropriate tests of a cycle's 'real' speed..." (Pinch and Bijker, 1987:46). Yet the design details of modern bicycles and how they came to predominate may seem both a matter of little consequence and a matter in which few would take urgent exception.

A slightly different term can, however, be employed to label much the same process of selecting particular technical configurations among multiple alternatives: "political" construction of technology. This is not to disparage the notion of "social construction"[2]. The bicycle illustration of "social construction" offered by Pinch and Bijker does have the unique and, in its context, laudable advantage of focusing attention on the historical contingencies implicit in the development of the bicycle. Attention is focused on the "underdetermination" of the design by natural facts and the associated contingency of the technological outcome on human participation,

without the possible distraction of sharply differing (political) commitments as to how the design "should" have come out.

The term "political construction" of technology, however, has the advantage of a different focus. While it works reasonably well in calling attention to the contingent nature of technology, it tends also to call our attention to the exercise of political power that may be implicit in the selection of one configuration for technology over others. In the science, technology, and society (STS) studies literature, there are many excellent illustrations of what might more aptly be termed "political" than "social" construction of technology. David Noble (1984) argues, for example, that the determining factor in the development of numerical control rather than "record playback" machines may have been a reshaping of the balance of power between management and workers, rather than any realistically defensible belief in the superior technical efficiency of numerical control. Langdon Winner's (1986:19-39) discussion of Robert Moses' low bridges as barriers to buses, and hence to low income people's access to suburbs and beaches in the New York area, also has the ring of "political" construction of technology. Winner's reference in the same essay to the development of automatic tomato picking machines usable only on large farms, and to the implementation of pneumatic molding machines in the 1880s as a way to break a union, offer further illustrations of what appear to be clear and consequential exercises of power in the selective construction of technology.

Subtle Exercise of Power

In focusing attention on the exercise of power often implicit in the selective development of science and technology, allegations of conspiracy and even of malevolent or self-serving intent may be advanced. No such allegation is, however, necessary to justify a focus on power.

> As far as I know, no one argued that the development of the tomato harvester was the result of a plot. Two students of the controversy, William Friedland and Amy Barton, specifically exonerate the original developers of the machine and the hard tomato from any desire to facilitate economic concentration in that industry. What we see here instead is an ongoing social process in which scientific knowledge, technological invention, and corporate profit reinforce each other in deeply entrenched patterns, patterns that bear the unmistakable stamp of political and economic power. (Winner, 1986:27)

Even where an exercise of power may be only implicit--i.e., entirely unrecognized and, as such, often not defined as an exercise of power at all--it may well remain a matter worthy of careful attention in the development of technology, just as it is in other areas of life.

Where there is a concern for the responsible exercise of power and for legitimacy within democratic traditions, awareness of the exercise of power and accountability for that exercise are logically matters of rudimentary significance.

There may, of course, be a wide range of opinion regarding the degree to which human actors actually choose or have the capacity to choose in matters of science and technology. In the world described by Ellul (1964), Mumford (1967, 1970), or Marcuse (1964), we may be virtually powerless to choose, or we may be so deeply conditioned to the rule of technology as to require vigorous shaking, at the very least, if we are to become active choice makers.

In practical terms, however, if we accept as fact the underdetermination of science and technology, there is room for attention to the process by which choices are made. What alternatives are there (or have there been) to the chosen path? How have those alternatives been selectively eliminated? The importance of such questions is asserted, implicitly or explicitly, by virtually every participant in the STS community who raises the issues of political construction of technology, whether or not they employ this term. Concern with the choice process, and the often suspect or regrettable consequences of widespread default in that process, may well be one of the fundamental origins of the STS movement (cf. Cutcliffe 1990).

Concern with the political construction of technology is very much heightened by an appreciation for the subtler workings of power. How do we know, after all, that any particular "advance" in science or technology is responsive to human needs or desires at either an individual or collective level? How do we know what people "really" want? Is it enough that people do in fact purchase the VCR or the microwave oven, for example, when it comes on the market? Is this enough to guarantee us that resource investments in these new technologies have been appropriate and that the public good has indeed been best served by the choice of this among all possible routes for technology development? Is this market behavior a sufficient guarantee that power, if you will, has been legitimately and responsibly exercised in choosing this evolutionary direction over others?

For many, of course, these are idle questions. Where, after all, is the exercise of power in the development of a VCR, for example? Surely there has been no significant <u>conflict</u> over whether or not a VCR should be developed. And is it not the proper right of those taking the risk and making the investment in new technology development to dispose of their own property in this way if they so choose?

Subtler notions of power[3], however, suggest that power may have been exercised in the decision to develop and market the VCR even without overt conflict or opposition to this technological thrust. Without proposing the abandonment of property rights, we may yet imagine conflict between a democratic shaping of science and technology, and a developmental path shaped by the interests of private property. The fact that "consumers" buy VCRs, furthermore, is no <u>a priori</u> guarantee that anyone's "real interests" are served by this new device; we have no data, after all, on what the outcome would be if people had been offered an "anti-VCR" as an alternative situated in a "non-consumer" world.

This may still sound like idle speculation. To make the matter more concrete, consider Langdon Winner's discussion of technology as an impediment to access and participation on the part of handicapped people (Winner, 1986:25). While there surely was no deliberate intent to prevent handicapped people from participating as other citizens do in public life, the use of curbs, stairs, and other technologies in traditional construction in this country long had precisely this effect. The (effective) exercise of power that prevented their participation was not intentional and long went essentially unrecognized, yet we collectively went about shaping technology in particular ways (to the exclusion of obvious alternatives that have been pursued since) that had a significant political effect.

In his handling of the subtler instances of the exercise of power, Steven Lukes (1974:51) offers a definitional refinement:

> Can A properly be said to exercise power over B where knowledge of the effects of A upon B is just not available to A? If A's ignorance of those effects is due to his (remediable) failure to find out, the answer appears to be yes.

He further explains that,

> The point...of locating power is to fix responsibility for consequences held to flow from the action, or inaction, of certain specifiable agents. (Lukes, 1974:56)

In the context of this definition, those who have designed and built curbs and stairways are at least potentially responsible for an exercise of power that long excluded handicapped people from public life. If the designers or builders could have found out about the impacts of their technology choices on handicapped people, then it may be that they should be held responsible for this effect.

If we adopt Lukes' notions of power, the social construction of science and technology may well be political in a rather pervasive sense. Every choice among avenues of development has the potential, at least in theory, of selectively foreclosing or disadvantaging particular patterns of life that could be of interest to certain members of society. As such, every such choice could be regarded as an exercise of power of real significance. The fact that no one appears to raise serious objections to a specific selection or developmental path, the fact that no vociferous advocate of an alternative path comes forward, still leaves the prospect that we may simply have failed to "find out" how those who remain silent might approach the choices afforded within the realm of scientific and technological possibility.

CTA and the Legitimate Exercise of Power

Does science and technology, as presently constructed, best serve human needs or aspirations, and has the selection process that brought us the particular science and technology now in place been democratic? There would appear to be room for concern that the political construction of science and technology, especially to the degree that it may involve subtle and less than overt exercises of power, indeed may not occur in a way that is entirely in keeping with the principles of our democratic tradition. If particular avenues of development are being selectively advanced, others effectively undermined, without an even-handed exploration of alternatives or in the absence of active efforts to get at the preferences and perspectives of all citizens, the exercise of power involved may not prove fully legitimate within a democratic tradition.

Acceptance of the underdetermined nature of science and technology, coupled with an appreciation for the potential subtleties inherent in the exercise of power, appear to call for a more conscientious approach to the development of science and technology, an approach that might be referred to as "constructive technology assessment."

Constructive technology assessment (as the term will be used here) strives to envision alternative technological futures that might serve alternative configurations of human values and commitments[4]. It is concerned not simply with specific alternatives to particular technological developments or with alternative configurations for particular developments. The question it addresses is not simply one of weighing the costs and benefits, even broadly conceived, of particular developments, but of probing alternative notions of "cost" and "benefit" and of framing

assessments in such a way as to address real choices among alternative "forms of life" (Winner, 1986:3-18). If we have become, as Winner suggests, "the beings who work on assembly lines, who talk on telephones, who do our figuring on pocket calculators, who eat processed foods, who clean our homes with powerful chemicals" (Winner, 1986:12), then we need CTA to begin addressing the question, who else could we be?

Legitimate (i.e., democratic) exercise of power in the development of science and technology calls for active efforts to construct a range of alternatives for choice, along with active efforts to comprehend and discuss the full range of reactions to those alternatives that might arise. CTA efforts along these lines will call for a good deal more than the usual "market data" or questionnaires targeting people's "values." A far more probing concern with human "cares, commitments, responsibilities, preferences, tastes, religious convictions, personal aspirations, and so forth" (Winner, 1986:156) will be required.

Ethnography and CTA

Schot (1992) has recently proposed three approaches to the actual conduct of CTA: "stimulating alternative [technological] variations, changing the [technology] selection environment, and creating or utilizing technological nexus." (The last of these focuses on institutional links and real world interactions between the variation process and the selection process.) While these approaches are developed in the context of examples taken from efforts to develop environmentally clean technologies, they appear to provide, as Schot suggests, good foundations for CTA in general. They are, in fact, indicative of interesting possibilities for extracting what amounts to CTA from ethnographic examinations of ongoing technology-related activities, and for developing CTA from almost purely theoretical exercises as well.

A variety of alternative variations and selection environments may already be available as elements of CTA if they can only be captured and formalized somewhat.[5] Ethnographic examination of ongoing departures from traditional norms may be especially useful in this regard, as may be seen from recent study of the "home power" movement in the U.S. (Tatum, 1992).

Although not widely recognized by government or the popular media, the home power movement has generated a host of alternative variations in the area of residential energy systems. In a technical sense, the core of the movement includes more than 40,000 home electric supply systems (mostly photovoltaic or "solar cell" systems), augmented by small home hydroelectric and wind systems, as well as substantially improved and more reliable 110 volt inverters and battery systems to store energy and convert to household current. New technological variations also include uniquely efficient refrigerators, lighting systems, well pumps, and other appliances, specifically suited to (more expensive) renewable electricity supplies.

Participants in the home power movement appear to be motivated by a desire for a reformulation of work roles (more varied, less specialized content, and shared rather than hierarchically structured responsibility). They also appear to seek a strengthened sense of community and different and less damaging relations with the natural environment.

Together, the alternative variations and differently constituted selection environment of the home power movement arise from what might be termed a newly created technological nexus.

Emerging from this new nexus is a very different "form of life" from those given consideration in the context of traditional economic or government policy analyses. There is, in the movement, a strong sense of "the coemergence of values and practices" (Bijker, 1993:130) and the usefulness of ethnographic methods as a means of escaping conventional mindsets is much in evidence.

In efforts to initiate CTA from ethnography of ongoing departures from traditional norms, it will be important to remember that the intent is not to argue that people should not speak directly for themselves. The argument is rather that it may be useful at least to try to know people better than they know themselves, or more accurately, to attempt to explain behavior, attitudes, and values in words that communicate better with outsiders than the words that a particular group may be willing or able to come up with on its own.

It should be emphasized as well that there will be no guarantee that the descriptions arrived at through ethnographic methods will more accurately reflect "real" interests than simple market data on the "consumption patterns" of the people under study. Certain knowledge of "real" interests inevitably remains beyond our grasp. The objective, instead, would be to contribute to a broadened conversation about the goals, objectives, and effects of scientific and technological "advance." In undertaking ethnographic analysis, we simply take the first step in admitting that we do not know (no individual, professional expert, or group knows) what people "want." In adopting an ethnographic approach, we admit that what people want may change over time and with changing circumstance--and even that we do not fully know what we ourselves want. In undertaking such analysis, we assert only that what we and others want may benefit from examination and discussion in a context of choice among practical alternatives for action[6].

CTA by Theoretical Means

While ethnographic studies of departures from the mainstream of technology development would, in essence, tap existing practical efforts to do what amounts to CTA, assessment efforts can also proceed from theoretical speculations. Consider, for example, the possibility of "success" in the development of an electric automobile with performance characteristics comparable to present gasoline-fueled cars. Substantial efforts are now underway to accomplish this advance in technology with relatively few very different alternatives apparently under consideration. Supposing, then, that we succeed. As a matter of theoretical speculation, what developments might we expect to follow this success? If the cost and mechanical energy requirements of the electric auto are comparable to those of present autos, can we expect substantial easing of the environmental problems associated with present autos, or more nearly a shift from auto to power plant emissions? Can we expect an easing of pressures on increasingly scarce energy supplies? Where will the new power plants likely to be associated with the approximate doubling of present electric power production required by a fully electric fleet be sited? What fuels will they utilize?

Strictly theoretical speculations such as this may lead us to a consideration of other alternatives for future technology development. We may probe possibilities for much lighter, lower energy, shorter range electric vehicles to be used only in local commuting. We may consider possibilities for demographic shifts, living closer to work and to essential shopping, that would simply eliminate the need for many trips.

Purely theoretical considerations, in other words, may effectively lead us to a critical examination of traditional selection criteria and to a collection of alternative variations. Where we are at a loss to come up with new theoretical directions, we may benefit by interactions with others who may be in a position to see things differently. In the transportation example, we might address the question of alternative transportation systems to a backyard tinkerer or an engineering student, or to someone who doesn't have the money to buy a car or to feed it gasoline. Conversations with people who may bring new perspectives to technology development can provide access, in effect, to possibilities for changes in the selection environment that can be pursued in purely speculative theoretical terms.

Much may be possible in the way of theoretical as well as practical CTA with relatively little government support. Both theoretical and practical approaches, on the other hand, by the very nature of their departure from, or questioning of, established patterns of science and technology development, are likely to require some degree of public funding. At a minimal level, a great deal might be learned simply by examining and reporting on efforts like the home power movement. At the opposite extreme, public funding could be (and to a degree already is being) used in the actual experimental exploration of alternatives such as those that might emerge from theoretical speculations. A certain amount of publicly funded CTA is already being done, either within governmental agencies, or through activist organizations[7] with other countries apparently in the lead (Vig, 1992).

An overall reduction in government intervention in the shaping of science and technology may, however, also be worthy of careful consideration in advancing a program of constructive technology assessment. It can be argued that democratic decision making is best assured when ordinary people directly confront actual alternatives for the development of science and technology. To the degree that people are naturally inclined to practice what amounts to CTA on their own, it may in some cases be well simply to get out of the way.

In a sense, "doing" CTA is nothing new. Surely most technology development efforts begin with more than one possible alternative and with some consideration of how the selection environment is or should be defined. The argument here again is simply that a full recognition of the underdetermined nature of technological advance and of the subtleties in the exercise of power implicit in that advance necessitate a more conscious and a more conscientious dedication to the process. In order to be sure that we have "found out" what directions might be preferred by particular individuals or groups, CTA needs to be pursued more actively. It needs to be pursued from a wider range of perspectives and to carry those perspectives farther in terms of their possible expression in alternative technologies. And it needs more closely to involve citizens to ensure both that a wider range of perspectives is represented, and that alternative developmental paths actually achieve broad consideration by those who ultimately are supposed to be represented in the choices that are made.

Where Do We Need CTA?

In an ideal world, CTA would be pursued continuously and on a broad front, not simply in response to specific technological proposals. Critical areas of need, however, might be located by certain signals. In areas where there appear to be unusual opportunities for commercial profit, for example, special attention to CTA efforts may be justified by the concern that broadly

democratic decision making may be overwhelmed by particularized economic interests. Areas in which appeals of an apparently unchallenged ideological nature are made may also be critical targets for CTA efforts.

The case of bioengineering may be a good illustration in the first category and technology development targeting "global competitiveness" may be exemplary in the second.

The potential for profit from commercial developments in the field of bioengineering requires little explanation. The problem is that that potential for profit may overwhelm less organized and less focused alternatives for technology development that could arise in a more broadly democratic decision making setting. Once particular bioengineering alternatives are proposed, whether they involve organisms engineered to help keep strawberries from freezing in the field or biological systems engineered to produce bovine growth hormone to enhance milk production, the potential for profit gives those proposals a life of their own. With strong arguments (i.e., profits) from well organized groups (i.e., corporations) in favor of these developments, the burden of proof shifts to opponents who in practice are generally required to come up with fairly specific arguments against particular products. In the case of "recombinant" bovine growth hormone (rBGH), for example, we hear objections that include the expectation of minimal direct benefit to consumers (prices are already low, given a surplus of milk on the market), possible concerns about human health effects, and possible increases in udder infections and other tissue reactions in cows. Four major corporations have, however, developed one or another version of rBGH. For one of them, Monsanto, rBGH is only the first of more than a dozen biotech products in a pipeline with $1 billion a year in projected sales and royalties, and research and development costs already amounting to $800 million (Roush, 1991).

Specific objections to rBGH or other bioengineered products may well not carry the day, and perhaps they should not. Yet there can be little doubt but that genetic engineering as a whole has the potential for "reconstituting the conditions of human existence" (Winner, 1986:10) in terms of continuing ecosystem transformations, man/nature relationships, and even the structure and content of human associations. It is difficult to regard that process of reconstitution as "democratic" in the absence of a countervailing balance to the highly focused profit incentive, and in the absence of equally aggressive efforts to explore and define alternative courses of development. Such a situation is expressive of a critical need for CTA efforts.

In the area of global competitiveness, there is the appearance of an appeal to unexamined ideological commitments indicative of a critical need for CTA. The phrase "global competitiveness" seems at times to have acquired a mesmerizing quality, silencing once insurmountable resistance to layoffs and other labor concessions, for example, where it is argued that global competition necessitates leaner and more efficient operations. Similarly, we seem to proceed without a blink in the apparent abandonment of traditional separations between publicly and privately supported R&D (separations once carefully guarded in the national lab system, for example), if that abandonment is proffered in the name of global competitiveness (cf. Hill, 1989). As developments of this sort take on an "automated" character, advancing without the apparent possibility of resistance or debate, there may be a critical need for aggressive CTA efforts. While the arguments for the obvious course of action may in fact be strong, their very strength may serve to eclipse alternatives with significant appeal from marginal or marginalized perspectives.

In the continuing development of science and technology, we too often confront what amounts to one and only one alternative. We accept it or, implicitly, we oppose it and embrace the social stigma and practical impotence of siding with a "non-alternative." It is as if we were presented with the choice of Mr. X for president, or no president at all, as if we were to choose between global competitiveness and nothing at all. In such a setting, and especially in the areas of critical need identified above, constructive technology assessment is essential as a tool to general enfranchisement and democratic choice.

Conclusion

In ongoing genetic engineering, "global competitiveness," and innumerable other technology development efforts, we are unquestionably engaged in "reconstituting the conditions of human existence." (Winner, 1986:10) Without vigorous constructive technology assessment, we are at best doing this as "somnambulists" (Winner, 1986). At worst we are reshaping the lives of others without their knowledge, participation, or permission. Recognition of the underdetermined nature of science and technology, an understanding of the subtle nature of power and its exercise in the selection of developmental paths, and a concern with democratic decision making, together constitute a compelling argument for new and more active practical and theoretical efforts to explore, define, and discuss a broadened range of technological alternatives for the future.

Notes

1. I owe the term "selective attention" to David Rose (1981).
2. Bijker, himself, appears to move more in the direction of political construction in recent work (Bijker 1993).
3. See especially Lukes (1974).
4. For comparison, see Schot's use (1992) of the term constructive technology assessment and his references to other uses of the term. Bijker (1993:129) also offers a characterization of "Orthodox 'technology assessment,' as exemplified since 1972 by the work of the U.S. Office of Technology Assessment," which he contrasts nicely with a constructivist approach, though without using the term "constructive technology assessment." See also Martin Rein's (1983) notion of "value-critical" policy analysis, which in many ways parallels that of constructive technology assessment.
5. Support for such a claim is actually widely available even in such classic studies as Small Town in Mass Society (Vidich & Bensman, 1968).
6. To a rough approximation, what is envisioned here is one means for beginning again to cultivate what Albert Borgmann (1984) has termed "diectic discourse."
7. The Natural Resources Defense Council headquartered in Washington DC, for example, has constructed arguments for transportation alternatives along roughly the lines of those outlined above.

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Total Quality Management as an Ethics Issue Mediated by Technology Transfer in Unsolicited Sociotechnical Interventions

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An unsolicited sociotechnical intervention is first an intervention where technology is coincident with a societal change and the change is seen through a languaging that comes from the acceptance of the technology (Maturana & Varela, 1988; Emery & Trist, 1973). Languaging is a cybernetic concept that cautions readers not to perceive language as an outside of system tool that can be used in observation. Instead language is a result of living and through living, renaming the world again and again. We exist in language.

The intervention is called forth by the defined societal system or a related super system in that at the very least, the technology is not invented in a vacuum. This is a sociotechnical intervention. An unsolicited intervention of this type is one where there is no identified social contract for learning discovery between the bearer of the technology and the participants in the societal system directly impacted by the technology (Dorsey, 1991). Technology is any collection of humans, machines, materials, and systemic and environmental information, organized to satisfy a customer directed purpose for a product or service. The delivery of the product or service to the customer is a technology transfer (Williams & Gibson, 1990). At any moment in time there are defined customers and providers of services or products, but customers and providers interchange roles as systemic need arises.

The foregoing definitions should be viewed as snapshots of the dynamic processes of interactions among the customer, the technology and the sociotechnical system wherein they reside. Or stated another way, the boundaries of all these ideas become amorphous as the intervention unfolds (Dorsey, 1991).

A different type of definition appears in a problematic way. Ethics is the collection of practices that aims for the establishment of equity and parity among humans. By its historical explicandum, it is born in injustice and unfairness; yet as it is actualized in morality (Jantsch, 1980), it moves to a greater injustice: stasis. It is in this conundrum between the dynamic, ever changing essence of humans, and the need to protect all humans through fair play that Total Quality Management makes its impact.

Total Quality Management is an ongoing process of process improvement. Its aim is to improve processes. An improved process is where organizational learning of the Model II variety (Dorsey,

1991) takes place. This type of organizational learning is delimited by the governing variables: valid information, free and informed choice, and internal commitment to the choice and constant monitoring of its implementation (Argyris & Schon, 1985). It is a learning to learn paradigm. We demonstrate this characterization of Total Quality Management by delving into the fourteen propositions of Edward Deming for quality management.

The fourteen propositions of Deming for quality management:

1. Create constancy of purpose.
2. Adopt the new philosophy.
3. Cease dependence on mass inspection.
4. End the practice of awarding business by price tag.
5. Improve constantly and forever the system of production and service.
6. Institute training on the job.
7. Institute a leadership of helping.
8. Drive out fear.
9. Break down barriers between departments.
10. Eliminate slogans, exhortations, and productivity based targets for work force performance.
11. Eliminate work standards prescribing numerical quotas.
12. Remove barriers preventing pride in workpersonship.
13. Institute a vigorous program of education and self improvement.
14. Put <u>everybody</u> to work on accomplishing the transformation.

These propositions are based on the Deming work, <u>Out of the Crisis</u> (1986). An interesting aside is how these propositions have been reported by the community. In particular, proposition 14 seems to be recast in terms of management initiatives, rather than an empowerment construct for all humans in the organization (Gaither, 1991; Walton, 1986).

The fourteen propositions are really a theory based on two axioms and twelve propositions. The two axioms are Propositions 5 and 14. Clearly, it is not possible to test if the organization is "improving constantly and forever the system of production and service." Nor is it possible to determine if "everyone has been put to work on accomplishing the transformation." Thus, these statements are assumed true without proof or a means of testability. Ergo, they pass the metatest for being axioms. The rest are propositions in the true sense of a theory. It is readily apparent that Proposition 9 is a direct result of Proposition 14, and that the rest are directly inferred from Proposition 5. Let us call Proposition 5, Axiom One, and Proposition 14, Axiom 2. And let us call the Deming collection of propositions, the Deming Quality Theory (DQT). The question now arises, "Is DQT a theory?" Because if it is, then it says that if an organization embraces DQT then the organization will be in a perpetual state of process improvement as defined in organization learning terms.

A theory must have consistent axioms, that is, it cannot generate theorems or propositions from these axioms that contradict each other. To test for consistency among the twelve propositions would involve combinations on the order of O(12!), or approximately k*479,000,000 combinations, k, a positive real number greater than one. Obviously, no one is going to attempt that with quill and parchment. Additionally, there are interpretative problems that will arise immediately with respect to the meaning of the words in the propositions. So how should we proceed? We can call on experience for recognizing clear problem areas, and leave the exhaustive proof for another time.

The purpose of Total Quality Management is to improve the processes of an organization so that it can remain in business. Is there anything in DQT that negates this? No, it appears that DQT implies its goal of continuous improvement. But what does it mean to remain in business? In the common body of knowledge, it means to stay ahead of the competition so that your share of the market sustains and nurtures your organization. What is the competition? Again, through common knowledge, other organizations seeking to get your share of the market so that it can sustain and nurture them. Now if you are a TQM organization and they are TQM organizations, who will stay in business if all are in a perpetual state of process improvement? How does DQT answer this? It doesn't do it directly, but it hints that the dilemma can be resolved in a non-threatening way.

Propositions 7,8,9 and 12 give clues that the boundaries between individuals in an organization have to dissolve in order for the organization to realize itself in a free and informed way. If competition means to maximize winning and minimize loosing to the other outside organization, which means ultimately to establish either a monopoly or a monopolistic oligopoly in the market, then how can a Total Quality Management organization prevent this single minded control system from reinfecting the Total Quality Management organization and undermining Propositions 7,8,9 and 12? Put another way, who does the organization find to be Dr. Jekyll inside and Mr. Hyde outside? Economic history tells us that there is no such thing as a good king. Such individuals practice fairness only for a short period of time, then they become obsessed with power and ultimately set or reinforce the process of self destruction for the organization they seek to lead. So how are we to have a TQM organization in a world of competition? Clearly, most workers want empowerment when given the opportunity to practice direct control over process improvement (Freire, 1973; Hendrick, 1993). And these workers prefer the dissolution of barriers among themselves. Furthermore, it is a reasonable inference that these workers don't want to be in a state of unemployment flux because their organizations are chasing short term profit models. So in a sense, stasis is welcomed as an ethical construct by most workers. But the employment stasis when combined with organizational learning becomes a dynamic state of being.

Every mistake is an opportunity for new learning. Change is natural and non-judgmental. Learning is ongoing. Such workers are not interested in 'beating the competition.' Instead, they are at times inwardly focused, testing the viability of their organization. When another organization improves its market position, these workers see this as an opportunity to learn how to improve further. They do not see the other organization as a bird of prey eating away at the nourishment that feeds these workers. And these workers understand that artificial barriers among workers couched in privilege and justified by unchecked profit drives, only destroy the ethical basis of fellowship among workers. These workers do not want a Dr. Jekyll and Mr. Hyde manager. They want a worker who is ethically consistent and open to learning to be their manager. These workers see the customer as their ultimate teacher. And they welcome the customer's involvement in all phases of the process that is in place to serve the customers' needs. Furthermore, these workers want all organizations to operate this way.

Now if stasis is seen as security in terms of keeping a job or maintaining the 'bottom line,' then process improvement is seen in terms of keeping an edge on the competition so that this security is maintained. Learning is limited in that what is learned does not challenge the validity of the structure that produces the profits to ensure the security. Errors are detected and corrected within this context. Everything is done to maintain the sense that competition is maximizing winning and minimizing loosing. This is a Model I system (Argyris & Schon, 1985). It is a closed system in that it defines new learning in terms of its structure and not its capacity to see structures. For Total Quality Management to work here, Axiom Two and thus, Proposition 9 must be suspended. In their place a pseudo axiom must be substituted:

14a. Take action to accomplish the transformation.

This is a weaker axiom than Axiom Two. It depends on collecting a 'critical' mass of workers and managers to effectuate the transformation of the organization. It assumes that only a limited number of workers will engage in the improvement processes. It creates an 'in' and 'out' group, axiomatically. It makes Proposition 9 impossible. A substitute proposition would be:

9a. Improve communication between departments so that the company mission of maximizing winning and minimizing loosing is clearly understood.

This proposition would also lead to a weakening of Proposition 8 in that 'fear of loosing or winning' could not be eliminated. We suspect that Proposition 4 would also be weakened in that the temptation to maximize profit could easily be influenced by awarding business to suppliers by price.

Thus, if an organization chooses to define competition as the process of maximizing winning and minimizing loosing, then the DQT

could not remain in-tact. Instead, a subset of the propositions would have to be employed.

If an organization chooses to retain any form of competition as a predator relationship with other organizations, then that organization will ultimately choose profit over quality. If the organization wishes to continue to be in business as a Total Quality Management organization, then quality is preferred over profit in critical decisions of viability. The existence of profit to a Total Quality Management organization is not the key defining variable of the organization's culture. It is one of many variables. Profit is a source of investment funds for continuous improvement of the organization's products or services. Part of the improvement process is the determination of prices so that reasonable portions of the customer's wealth is burdened. Profit gouging is an inordinate burden on the customer's wealth. Such a practice is wasteful because it diverts investment from true societal needs. A Total Quality Management organization can think this way because by Proposition 4, it requires all other organizations to be of the Total Quality Management type. Thus, a Total Quality Management organization is a societal organization, and it finds its identity with other organizations in an interweave process of reflection. It cannot practice the maxim, "I got mine, now you get yours!" It must practice the ethic, "Let's get ours, together." Thus, a TQM organization must abandon competition as a construct for doing business.

A Total Quality Management intervention is not solicited by the whole organization. It is resisted because by Propositions 7,8,9 and 12 it calls for the end of isolation and wasteful privilege among workers. Workers are trained in our business schools and schools in general to expect privilege that separates them from their fellow workers as a reward for helping the organization meet its profit objectives. A Total Quality Management intervention is perceived by many proponents as an aid in improving the organization's competitive lot (Evans & Lindsay, 1993). Thus, workers are not open to a joint research relationship with the proponents of Total Quality Management. They see no value in change because they have no ownership stake in the organization. The organization produces security by maintaining competition. Workers understand this, and are not prone to tamper with a construct that feeds them, for a construct that asks them to take risks. But when, senior management proposes that Total Quality Management be embraced by workers, to improve the organization's competitive position, workers see Total Quality Management as just another tactic to improve economic security. Senior management sees the same thing.

In the intervention, the interventionist is key. S/he must be a zealot for justice (Argyris, 1990). If not, then the intervention goes very slowly, and does not penetrate the soul of the organization (Denton, 1991). It produces short term gains in error analysis and worker morale through the Hawthorne Effect. For Total Quality Management to work, the issue of privilege between

workers must be confronted. This privilege system is what prevents the organization from freeing itself to seek continuous improvement as a way of life.

Since the Total Quality Management intervention is introduced in a non-threatening way: to spur competition; under the competition guise, direct dialogue about privilege can take place as an inquiry about worker cooperation. In time, the workers will reject privilege as a means of demarcation. This depends greatly on the interventionist.

Ending this working paper, we posit that we must respect the impact of illusion over time. Intrinsically, business organizations change very slowly. The reasons are varied; but a sense of self preservation seems to drive most analyses. Pretension should be expected, and with this pretension, a well orchestrated denigration in the academic media of Total Quality Management as an effective alternative to stasis.

Total Quality Management is a revolutionary construct. It does what the Socialists and Capitalists could not do: marry each other in a practical and viable union, producing a new political economic system.

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SILENT SPRING: THE MYTH OF TWO CULTURES

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Because of her courage to be a whistle-blower on the effects of chemical pesticides, and her capacity to be a reconciler of what C.P. Snow called the "two cultures" of scientific and humanistic studies (the arts), Rachel Carson may be seen as an iconoclast. Presenting her perspective with grace and precision, Carson took on the Juggernaut of the chemical companies and their supporters: government agencies, trade associations and their journals, popular magazines, and university scientists who obtained grants from the chemical industry. Carson predicted the attempts to discredit her that followed the publication of Silent Spring, so her strategy was to write a book, in her own words, "built on an unshakable foundation." (Levin, 1978:2) Representatives of powerful interests sought to devalue Carson's study by questioning her credibility on several counts, among them, her gender.

Since the book was so carefully researched and written, the attacks on Carson were personal, rather than focused on the data or conclusions in the text. Furthermore, these verbal assaults tended to be based on timeworn, biased assumptions about the character of women. For example, Carson's work was denounced by Time as being replete with "emotionalism" and "oversimplification." (Levin, 1978:8) Carson, herself, commented on her detractors: "I am a bird lover, a priestess of nature, a devotee of a mystical cult having to do with the laws of the universe which my critics consider themselves immune to." (Levin, 1978:3)

As Paul Brooks points out in his "Foreword" to Silent Spring, "Rachel Carson was a realistic, well-trained scientist who possessed the insight and sensitivity of a poet." (Brooks, 1962:xiii) With a piercing vision, she avoided false dichotomies. She did not suffer from that "disassociation of sensibility" T.S. Eliot warned against in which feeling and thought are deemed to exist in distinct spheres. (Eliot, 1932: 246) She eschewed the polarization in which lucidity is associated with the quantitative, rational, and objective male principle, as opposed to the qualitative, sensual, and subjective female principle. Because of Carson's ability to communicate skillfully her precise scientific knowledge in combination with her respect for life, she inspired the modern ecological movement. Rather than appearing dated, her vision becomes more relevant as time passes.

Encouraged by her mother, Carson exhibited a great sensitivity to nature from the time she was a young child. At an early age she was also a voracious reader as well as a prolific writer. At ten years old, one of her stories was published in a children's magazine; at eleven, she received three dollars for a school essay (Levin, 1978:8). She began college majoring in English, but by the middle of her junior year, she was a zoology major. During the course of her career, she forged bridges between her enthusiasm for the natural world and her profound love of literature. Throughout Silent Spring, literary references are used to underscore a point. This use of literature not only serves to clarify ideas, but also to evoke a feeling, to remind the reader of the human, as well as the merely intellectual, responses to an observation.

For example:

> The world of systemic insecticides is a weird world, surpassing the imaginings of the brothers Grimm--perhaps most closely akin to the cartoon world of Charles Addams. It is a world where the enchanted forest of the fairy tales has become the poisonous forest in which an insect that chews a leaf or sucks the sap of a plant is doomed. (Carson, 1962:32-33).

> This system. . . deliberately poisoning our food, then policing the result--is too reminiscent of Lewis Carroll's White Knight who thought of a 'plan to dye one's whiskers green, and always use so large a fan that they could not be seen.' (Carson, 1962: 183-184).

In order to give corporeality to the concept of "death-by-indirection," the effect of "systemic insecticides," Carson uses the Medea myth (Carson, 1962: 32). Medea, in her rage at her husband for abandoning her, not only uses the poison robe to destroy her rival for her husband's affections, but also destroys those whom she is obligated to protect, her own children. Systemics are chemicals that have an extraordinary character, for they transform plants or animals into a kind of "Medea's robe," poisoning whatever comes into contact with them. In addition, like "Medea's robe," systemics are devious, for they endanger not only what they touch directly, namely the dog whose blood is made poisonous, but also the flea that bites the dog (Carson, 1962:33).

When systemics are applied to seeds, the effects are evident in the following plant generation, so that the Medea myth serves as metaphor, as the progeny, the future, is disastrously affected. Thus, it is clear that Medea's understandable anger becomes insane rage when the desire for revenge has no reasonable limits. Similarly, the desire to get rid of so-called "pests" becomes irrational when the means employed threatens organisms

that are only indirectly connected with the offender. Furthermore, it is becoming increasingly clear that the urgency to destroy these "pests" compromises the ecosystem and thus endangers the future of the planet.

Carson does not just happen to use literature to put forth ideas vividly; rather, her approach is at the heart of her vision. From the beginning of Silent Spring, where she quotes from Albert Schweitzer, John Keats, and E.B. White, the aesthetic sensibility that informs her work is evident. With deft strokes, yet with child-like awe, she reveals the emptiness of what sometimes passes for sophisticated technology. But in no way does her approach, which unifies the supposedly disparate worlds of science and the arts, detract from her analytical rigor. Instead, her ability to synthesize realms often treated as discrete enhances her argument. With the appreciation of a lyric poet, she perceives the creation as indivisible. Her work is not only a cogent scientific study; it is a song of praise.

> Who has made the decision that sets in motion these chains of poisonings, this ever-widening wave of death that spreads out, like ripples when a pebble is dropped into a still pond? Who has placed in one pan of the scales the leaves that might have been eaten by the beetles and in the other the pitiful heaps of many-hued feathers, the lifeless remains of the birds that fell before the unselective bludgeon of insecticidal poisons? Who has decided--who has the right to decide--for the countless legions of people who were not consulted, that the supreme value is a world without insects, even though it be also a sterile world ungraced by the curving wing of a bird in flight? (Carson, 1962:127).

The following questions emerge: Why was Carson's work so perversely misconstrued? Why was Carson, herself, so misrepresented and so vilified? Did her work threaten more than the chemical industry? Perhaps the answers to these queries can be found in the twisted values inherent in the assumption that there is a dichotomy between the cold, hard facts of a presumably masculine inclination to give emphasis to science and an awareness of economic reality, and a supposedly feminine urge to give primacy to sensibility and reverence for mother earth. Janice Law Trecker (1974:352-356) has described the distortion engendered by reinforcement of sexual stereotypes, and David Noble (1992) has lamented the consequence of the masculinization of Western science. Shirley M. Tilghman (1993:23) has pointed out that "The culture of science evolved in a period when it was being practiced exclusively by men, and that has greatly influenced its outcome." She continues, "It is a men's game and it continues to be played by men's rules."

Carson's iconoclastic avoidance of the dualistic mode of perception in which science and art are treated as antithetical encouraged her to integrate her appreciation of nature's majesty with scientific imperatives. Respecting the interdependence of biological systems made available to her the understanding that the destruction of nature for short-term goals served neither the planet nor humanity. Making reference to Robert Frost's poem, "The Road Not Taken," she cautions that the "only chance to reach a destination that assures the preservation of our earth" is to use the road "less traveled by," the biological solution based on an understanding of "the whole fabric of life." (Carson, 1962:277-278) Perhaps, she is also warning us that it is at the peril of humankind that cognition is treated as if it were divisible into male and female, and that culture is perceived as if it were separable into analytical inquiry (science) and aesthetic appreciation (art).

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ORDINARY AND EXTRAORDINARY WOMEN IN SCIENCE

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We, a geologist and an astronomer, came to study the history of women in science through the same route many followed: To answer the question why are there so few women in science in our textbooks, in our course syllabi, and, therefore, in our awareness. Ask anyone to name a woman scientist and Marie Curie is the first, and often the only, answer. Women scientists whose work affects our daily lives are forgotten in our textbooks and unrecognized by many of us--even those of us who are scientists or "scientifically minded." As examples, many of us are not familiar with Ellen Swallow Richards, a chemist, who worked on improving sanitation in the home and in controlling municipal water quality. Nor are we cognizant of Gladys Hobby who developed the antibiotic, oxytetracycline.

Subsidiary questions then arise when we re-discover important female historical figures in science. Which scientists are recognized in our textbooks and what are their accomplishments which merit their inclusion in textbooks? We stress inclusion in textbooks, because, as Kuhns (1970) says, textbooks are the primary source of authority from which "scientists and laymen take much of their image of creative scientific activity" and they are the primary "pedagogic vehicles for the perpetuation of normal science." If women scientists are not included in textbooks, then it follows that we assume their contributions were non-existent or insignificant.

Thus, we came to look at "ordinary" and "extraordinary" scientists. The ordinary scientists comprise most scientific workers whether male or female. These scientists were not particularly recognized for their contributions to science in their times or later. The

"extraordinary" scientists are the Nobel-prize-winning scientists or the like who were often rewarded and acknowledged during their lifetimes or soon thereafter. It is the "extraordinary" scientist whose accomplishments are heralded in textbooks and imprinted in our consciousness of who are the great scientists. Most of us in science realize that science is a collaborative and cooperative endeavor with many people contributing to the development of new ideas or products.

We divide our presentation into two parts: first, we will discuss women astronomers and their representation in astronomy textbooks and history of science; second, we will look at two contemporary 19th century women scientists in Britain.

Women Astronomers

During the 1600s and 1700s women who wanted to work in astronomy were able to do so only in the home. The wives, daughters, or nieces of astronomers could act as their assistants because observational astronomy was conducted at private residences. Working outside the home, at a university where theoretical astronomy was studied, for example, was forbidden. By the mid-1800s the situation slowly began to change.

Maria Mitchell was the first American female astronomer to be recognized for her accomplishments. Her astronomical work, too, began in the home as she assisted her father in doing navigational and timekeeping work for the fishermen of Nantucket Island. She later became famous both for her observations, her impact through teaching, and her attempts to open the doors of astronomy to women. She was the first American to discover a comet and was hired as the first astronomy professor at Vassar College. She encouraged her female students to think for themselves, continue their studies and pursue careers.

The United States was just beginning to build astronomical facilities, and it is interesting

to note that there were no male counterparts of Mitchell. Not until the latter part of the nineteenth century would the US astronomical community rise to a par with the rest of the world.

Unlike Mitchell, the women who worked at the Harvard College Observatory during the late 1800s and early 1900s remain anonymous to most of us. Even though the knowledge they gathered is taught in every astronomy classroom and used in each research laboratory around the world, few have ever heard of Annie Jump Cannon, Henrietta Swan Leavitt, or Antonia Maury and they are seldom incorporated in any astronomy textbook.

Maria Mitchell (1818-1889)

Maria Mitchell was born in 1818 on Nantucket Island, Mass., and was the daughter of an amateur astronomer father and librarian mother. Although her formal education ended at age 16, she continued her studies through self-teaching. During her life she was awarded three honorary doctorate degrees (Ogilvie, 1986).

She was catapulted into fame after the discovery of a comet on October 1, 1847. A gold medal given to her by the king of Denmark was the first given to an American and the first ever to a female (Ketchum, 1967). She was the first woman elected to the American Academy of Arts and Sciences and the American Association for the Advancement of Science. In 1865 she was named professor of astronomy and director of the observatory at the newly founded Vassar College for women (Ogilvie, 1986). Her salary, however, was only one third that of her male colleagues. She, as well as most of her female counterparts at other women's colleges, lacked adequate equipment to conduct extensive research and could not join the men at seminars and meetings to discuss the most recent findings (Langford and Slavings, 1990).

Mitchell made a deliberate choice to commit herself to observation and teaching. She

stressed mathematical astronomy, having her students observe comets and calculate their orbits, for example. She disapproved of lectures, preferring small classes and individual attention (Ogilive, 1986). She encouraged her students to think, imagine, question, and propose new ideas (Ketchum, 1967). Warner (1979) described her as "a popular symbol of women's emergence from dependent domesticity into the public world of science."

Mitchell considered the prevalent view ridiculous that women were innately unsuited to mathematics and science (Ogilive, 1986). Concerned about the status of women and their educational and career opportunities, she aided in the formation of the Association of American Women (Kidwell, 1990). She became a symbol of the woman scientist and proved that society needed help in accepting women scientists (Abir-am and Outram, 1987).

The astronomy of Mitchell's youth radically changed from a practical subject of the surveyor and navigator to a theoretical one after the introduction of photography and spectroscopic analysis (Wagner, 1979). I believe it was a contributing factor to the era of the forgotten or ordinary women in astronomy. Thousands of photographic and spectroscopic plates were being generated at observatories and they needed to be analyzed. These analyses took large amounts of time and meticulous work by greater numbers of people. Less work was done by a single person; most projects were undertaken by teams.

<u>The Ordinary Astronomers</u>

In 1881 Edward Pickering, the fourth director of the Harvard College Observatory (HCO), fired his incompetent male assistant stating his maid could do a better job of copying and computing. She did, and she worked at the observatory for thirty-four years. Her managerial skills were also excellent, and Pickering put her in charge of a staff of twenty assistants. The group was dubbed "Pickering's Harem" by some (Rossiter, 1982). A total of

forty-five women worked at the observatory during Pickering's tenure (Rubin, 1986).

HCO began the tradition, which was copied around the United States and in Western Europe, of employing teams of college-educated women to conduct massive surveys of spectra, brightness, positions, and motions of stars. They were paid at much lower salaries than those of the observers (males) and therefore large amounts of work could get done with less expenditure (Warner, 1979). These inequalities in salaries and career tracks of men and women in astronomy began at the entry level, placing most females on a track with limited mobility, low pay, and little room for intellectual independence while many men were able to make larger salaries, move upward, and achieve scientific standing (Langford and Slavings, 1990).

By the 1890s many observatories resembled industrial factories but produced knowledge rather than manufactured products. The workers were mostly women, human "computers," who reduced data for the director (Kidwell, 1990). Many of these women were coming out of women's colleges and were too well-educated for this work which was the only job available to them (Wagner, 1979).

Annie Jump Cannon (1863-1941), Henrietta Swan Leavitt (1868-1921), and Antonia C. Maury (1866-1952) were three of the women employed by Pickering. They are examples of the ordinary scientists who have not received the attention they deserved.

Annie Cannon was born in 1863 in Dover, Delaware, the daughter of a ship builder/state senator. Her mother was interested in astronomy and introduced the stars to her young daughter. After graduating from Wellesley College, Cannon joined the staff of HCO. She examined the spectra of stars, classifying them into groups (Ogilive, 1986). Each set of spectra was less than an inch long, and one photographic plate showed hundreds of stars. She could classify them at a rate of three per minute and was very accurate (Kidwell, 1990). She

rearranged the spectral classes of stars into a more logical sequence which is used by all astronomers today - OBAFGKM (Spradley, 1990). In 1913 the International Solar Union accepted her system as the international standard (Kidwell, 1990). Using this system, she classified more than 350,000 stars (Wagner, 1979) and published the list in the Henry Draper Catalogue and the Henry Draper Extension but under the name of the HCO, not her name (Ogilive, 1986). None of the introductory astronomy books used in college classrooms today lists her name even though every one cites her work.

Despite her accuracy, her research and her observations which were original and innovative (Luther, 1980), Cannon never moved from the ranks of "computer" to faculty member. Although she received six honorary degrees (including the first doctorate in science given to a female by Oxford University), she was nominated but never elected to the National Academy of Sciences (Kidwell, 1990).

Henrietta Leavitt was born in 1868 in Lancaster, Mass., the daughter of a Congregational minister. She studied at Oberlin College and graduated from Radcliffe College. Because of a serious hearing problem, she volunteered at HCO for seven years before being hired as a "computer" (Ogilive, 1986). Beginning as an assistant in the measurement of variable stars, she eventually became head of the photographic stellar photometry section. After studying 1777 variable stars in the Magellanic Clouds, Leavitt developed the Period/Luminosity Relationship for Cepheid variable stars (Mitchell, 1976). It is used to determine distances to intra- and extra-galactic objects (Ogilive, 1986). Before she discovered this, astronomers had no means of calculating distance to faraway objects. She was not permitted to pursue her discovery, however (Rubin, 1986). "...Pickering relieved Miss Leavitt of her discovery and sent her back to collecting and cataloguing other variables, explaining that it was a computer's duty to collect

information--not to formulate scientific theories" (Spangenburg, 1979). A later HCO director, Harlow Shapely, used Leavitt's knowledge and determined that the sun was not the center of the Milky Way Galaxy (Spangenburg, 1979). Miss Leavitt died of cancer at the age of 53 (Ogilive, 1986).

Antonia Maury was born in 1866 and was a niece of Henry Draper whose widow had endowed the new department of stellar spectroscopy at HCO which Pickering directed (Hoffleit, 1952). After studying with Maria Mitchell and graduating from Vassar College, Maury was hired by Pickering. She determined the period of revolution for his newly discovered spectroscopic binary star Mizar, the middle star in the handle of the Big Dipper, and discovered a second binary (Spradley, 1990). Maury also discovered two distinct types of stars in the same spectral class. This discovery lead to Danish astronomer Ejnar Hertzsprung's pioneering work with giant and dwarf stars (Wagner, 1979). After a conflict with Pickering, Maury left and spent over 20 years teaching. She returned to HCO when it was under a new director (Spradley, 1990).

Despite the fame of Maria Mitchell and the important discoveries made by Cannon, Leavitt, and Maury, the American women of astronomy receive little, if any, coverage in astronomy textbooks. Only Leavitt's name has appeared in any of them. Other males are described, however, who, I feel, contributed much less. Tycho Brahe, for example, is found in every book and talked about in every introductory astronomy course despite the fact that he added <u>no</u> new innovative astronomical knowledge. After someone's name appears in a textbook, it seems to be cemented in history. The names of these and other women astronomers should be included in textbooks so that everyone learns that females have contributed to astronomy, too.

In 1976, when the Smithsonian Institution opened the Air & Space Museum, the initial

planetarium program gave a history of the 200 years of astronomy in America. Only male astronomers were mentioned and all but one were white (Rubin, 1986).

Two women scientists in 19th century Britain:

The extraordinary: Mary Fairfax Somerville and the ordinary: Mary Elizabeth Horner Lyell

Mary Fairfax Somerville (1780-1872) and Mary Elizabeth Horner Lyell (1809-1873) were contemporaries, although their life histories and contributions to science show little in common. One was self-educated despite the efforts of her family, both nuclear and extended, whereas the other was nurtured in an academic environment and encouraged to study. One received many honors in her lifetime for her scientific contributions, the other was best known as the charming wife of a famous man.

Mary Somerville was educated haphazardly in Scotland, although she came from a relatively well-educated family. After her father, an officer in the British Army, returned to Scotland and discovered his daughter "running wild," he sent her to a girls' school where she was taught to read by memorizing pages of the dictionary (Ogilvie, 1986). Her one-year stay at that school was so dreadful that Mary Somerville complained of that ill-treatment for decades. Her parents thought that one-year's worth of formal education was sufficient for Mary ("for a girl" was unstated but understood), because already she read too much and sewed too little (Alic, 1986, Osen, 1974).

Mary Somerville discovered algebra while reading a fashion magazine (the equivalent, I expect, of today's "Seventeen"). She taught herself algebra, but kept her efforts from her parents who thought that learning higher mathematics would drive her mad. Her father knew a woman in an insane asylum who was obsessed with longitude (Alic, 1986). Mary's painting teacher introduced her to geometry when they tackled perspective. Mary memorized Euclid's

"Elements of Geometry," which she had obtained from her younger brother's tutor, because her parents confiscated her books so she would not study so much. At night, Mary mentally reviewed the memorized pages of Euclid's geometry before she slept.

Marriage to Grieg and early widowhood left her financially independent. At the age of 33, she was ecstatic that she could buy her own library of math and science books (Osen, 1974). She wanted to immerse herself in the study of math and the natural sciences. After three years of independence, she married a second time. Fortunately, unlike her first husband, Mary's second husband, Somerville, encouraged her interests in mathematics and science. Mary accompanied him, an army surgeon, on his many trips to Europe. She and her husband knew, corresponded with, and entertained most of the great scientists of Europe.

When she was 50 the Society for the Diffusion of Knowledge asked her to translate, explain, and comment upon Laplace's "Mecanique Celeste." Her explanation of the mathematics necessary to understand this important work became the preface to "Mechanics of the Heavens" published in 1831. The preface was published separately from Laplace's work and was used as a college textbook for nearly 100 years. Laplace considered her one of the few who understood his work and said that she was one of only two women who had sufficient mathematical background to understand his work--the other was a Mrs. Grieg. Laplace did not know that Mrs. Grieg and Mrs. Somerville were the same person. Mary was denounced both by the House of Commons and the Church of England as being a "godless woman" for writing "Mechanics of the Heavens" (Osen, 1974).

Mary wrote three more treatises which made physical laws familiar and understandable to laypeople, but which were of sufficient depth and authority to be of interest to the scientist. She was well-honored within her lifetime, but no one noticed the irony of some of the accolades

bestowed upon her. As examples, her bust was placed in the Great Hall of the Royal Society--a place where she, as a woman, could not step. Societies on both sides of the Atlantic which did not permit women as members or even in the audience gave her numerous awards. Praise for her was particularly strong in scientific societies at that time because she was a "womanly woman:" wife, mother, society matron, as well as scientific author.

Mary Somerville regretted her role as "society matron," however; she said that she was required by her contemporaries to interrupt her work for visitors even though the visitors were unexpected and unwanted. How she wished, she said, that her work could be accorded the respect a man's work commanded--that she might continue with her writing and studying without interruption (Osen, 1974, Russett, 1989).

For the past two years Richardson has worked on unearthing the scientific contributions of Mary Elizabeth Horner Lyell by reading primary material in the forms of letters (both Mary's and Charles') and journals. Mary Lyell was a conchologist and was responsible, for example, for the collection and study of land snails in the Canary Islands in 1854 (Wilson, 1972). She accompanied her husband, Charles Lyell, one of the foremost 19th century British geologists, on many of his geological excursions which provided him, as the voyage of the "Beagle" did for Darwin, with many modern analogies and metaphors for the study of fossils and their evolution. She also participated in the discussions on evolution between Lyell and Darwin (Wilson, 1970) and her work on snails on the Canary Islands was analogous to Darwin's work on birds and tortoises on the Galapagos Islands.

Unlike Mary Somerville, Mary Lyell was well-educated by tutors. Her father, Leonard Horner, was a professor of geology who taught in both England and Germany. He was determined that his sons and daughters would be educated. Mary's younger sister Katherine,

who married Charles' younger brother, was a well-respected botanist. Mary Lyell was fluent in French and German and learned Spanish and Swedish in order to assist her husband with his readings and correspondence with other European geologists. She not only worked with Charles in the field by sketching and painting geological structures and cross-sections, but she packed his clothes, geological equipment, and his geological specimens. She had primary responsibility for the cataloging of fossil, mineral, and rock collections.

Although it is impossible to separate her contributions from that of her husband's, I can say with certainty that Charles Lyell could not have accomplished what he did without his wife's scientific support. Charles Lyell said of Mary Somerville that had she been married to another mathematician, "we should never have heard of her work. She would have merged it in her husband's, and passed it off as his" (Alic, 1986:190). Although some geologists may claim that Mary Lyell did not have any original geological thoughts, I find it curious that Mrs. Louis Agassiz writes Mrs. Charles Lyell about the glacial geology of South America. If the women were not intimately involved in geology and knowledgeable about it, why did not Mrs. Agassiz write Mr. Lyell or Mr. Agassiz write Mr. Lyell? One cannot claim that it was not considered "proper" for women to correspond with men who are not kin because Mary Lyell had a long and fruitful correspondence with William Prescott.

Other geologists, such as Murchison (see Wilson, 1972), mention the attendance of Mary Lyell at special meetings of the London Geological Society and the interest she demonstrated in those lectures. She clearly had a deep understanding of geology, but her knowledge was not acknowledged by either her contemporaries or later historians of science. She truly represents the ordinary scientist whose contributions have been lost to us. She also represents the woman scientist whose work was subsumed within that of her husband, father, or brother.

<u>Conclusion</u>

The nature of science and research today are such that most scientists, both women and men, are "ordinary" and unknown to the general public. Discoveries are made daily, usually by teams of people. Knowledge grows and changes so rapidly that we may be aware of the discoveries, but we readily lose track of the discoverers. The directors of research laboratories are more well-known than the numerous workers in their laboratories and are frequently honored for the work done by the laboratory as if the work had been conducted individually.

By incorporating both the extraordinary and ordinary scientists in our lectures and syllabi, we assure all our students, both females and males, that important work has been done by the ordinary but important scientist.

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WOMEN AND TECHNOLOGY: FEMINIST PERSPECTIVES

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I have a background in both education and industry. After finishing my first degree, I taught school for a number of years; mathematics, mostly. During those years, I also *studied* mathematics and computer science. I was fascinated with what goes into the teaching and learning of mathematics. But soon after I started work on my masters in computer science, I found that I also needed to know what people with such an education do *outside of the classroom.* So I found out. I took a computer analyst position in an engineering research environment. For the first time, I got to work among adults who were interested in the technical, just as I was. I found out a lot about what goes on in the engineering workplace. I found out it wasn't an altogether satisfying place for me. The other women scientists and engineers I knew also seemed to struggle. I came to realize that every woman I ever talked to could tell stories of having been treated as if invisible, while men took credit for ideas she had put forth.

Women engineers have overcome the social stereotypes which, in the past, effectively excluded women from technical studies such as mathematics and the sciences. But still, scientific and technological endeavor outside the classroom, particularly in the engineering fields, includes relatively few women and seemingly little influence from women. When women do participate, are they merely carrying out the masculine agenda that has been in place all along, thus further masculinizing science and technology, as suggested by Hacker (1989)? Or are they transforming science and technology with contributions that result in a more broadly inclusive set of technologies and technological improvements, i.e., technologies that are comprehensible, accessible, and useful to a broader range of people? Should women scientists and engineers strive to be like men scientists and engineers, or should they strive to bring to science and engineering a broader perspective than is possible when only men are scientists and engineers?

Women from many different disciplines -- the natural sciences, sociology and anthropology, philosophy and history -- contribute to the feminist critique of science and technology, and their perspectives reflect their intellectual interests and academic training as well as their feminist sensibilities. Harding (1986)

distinguishes five areas in which feminists have explored the relationship between women and science: equity studies; studies of the oppressive uses of science; the critique of what is chosen (and what is not chosen) for scientific study; the criticism of "science as a text," with its illumination of guiding metaphors and hidden agendas; and epistemological inquiries into what counts as knowledge and why.

The work along these various lines of thought and inquiry does not lead to a unified feminist standpoint with respect to science and technology. In fact, feminists are in conflict in their critiques of science and technology, as Longino and Hammonds (1990) outline so well. How do we know reality? What counts as knowledge? What social change do we want our science or our critique of science to promote? These are the issues at the core of the conflicts.

Some feminists who study relations between gender and science apply the methods of science to reveal the inequities of women's access to science and its social benefits. Sells (1973) has described mathematics as a "critical filter in the job market." Tobias (1978) has identified "math anxiety." Turkle (1988) speaks of the "computational reticence" of women who avoid risk-taking and hacking strategies with computers, and prefer instead a comprehensive pre-understanding of the computing environment. Fennema and others have described and measured affective variables associated with the learning of mathematics. Such variables include confidence, motivation, spatial ability, sex-role congruency, perceived usefulness, and family, school, and societal expectation. The Fennema-Sherman Mathematics Attitude Scales have been widely used to investigate the affective domain in the learning of mathematics. But as Fennema points out, the standards of mathematics achievement are biased in favor of men. She recommends that research into an appropriate mathematics education agenda is needed. Such research could guide the way to reforms in curriculum (what we teach) and instruction (how we teach it). Such research would need to take into account not only affective variables but also such equity issues as equal opportunity to learn mathematics, equal educational treatment, and equal outcomes of mathematics education.

Hacker (1983, 1989) looks back at least 5,000 years to find the beginnings of our present day style of engineering and technology, with its emphasis on fragmentation, control and domination, hierarchical organization, speed, and exclusion of women. She points out that engineering was exclusively associated with the military until late in the 1700s, when the field of civil engineering began to emerge, eventually giving us grand bridges, canals, railroads, etc. She traces the development of engineering in America, through the establishment of the land grant universities, to the professionalization of the engineering disciplines, and the

exclusive status claimed for members of these professions. She also shows how mathematics tests became the gatekeepers for the engineering professions.

Hacker and others, notably Garson (1988), have studied how technology in the workplace impacts women and keeps them oppressed and excluded in significant ways. Garson details how the ideas and methods of science and technology have been applied to the mechanization of such realms as fast food restaurants, airline reservations systems, the social work profession, secretarial services, and even engineering. She shows how the mechanization process gives formerly interesting and satisfying work over to machines, and leaves much of the remaining work mindless, and overly fragmented.

The feminist research I have been describing here would be classified by Harding (1986) and Damarin (1992) as feminist empiricism. The work has been done by feminists, and it has been done using the traditional methods of science with their emphasis on objectivity. Such studies have contributed greatly to our pool of scientific knowledge and to awareness of women's concerns with respect to science and technology. They have also served to calibrate the notion of objectivity in the study of gender and science, mathematics, and technology. Harding, however, makes the point that feminist empiricist research actually "subverts empiricism" because it demonstrates that the relation of the researcher's standpoint to the results of the research is certainly other than entirely "objective."

As an alternative epistemology to feminist empiricism, Harding and Damarin consider the feminist standpoint. Hartsock (1983:283) first proposed a feminist standpoint, based on the Marxian idea of the proletarian standpoint, as "an important epistemological tool for understanding and opposing all forms of domination." Damarin enumerates "important features" of feminist standpoints; among them, the following: Those who are disadvantaged and oppressed have a standpoint from which they can see aspects of the world which are not visible to those of greater advantage, who, in any case, are likely to have greater interest in maintaining the status quo. The construction of knowledge is an on-going process involving both the knower and the known. Knowledge is value-laden, changing, and political in nature.

The use of critical techniques from the scholarly traditions of the liberal arts and the humanities has provided feminists a powerful tool for the elucidation of the underlying metaphors and agendas of science and technology. While much of Hacker's sociological work is scientific in its methods, there is much of it that relies on historical interpretation. Bush (1983) also uses this critical method. She cites two examples from history in which technological change eased burdens for both men and women, but ultimately yielded authority and autonomy for men,

while leading to reduced social and economic status for women. The first example is the story of the domestication of horses by the Native Americans of the Great Plains. The second example is the story of the introduction of diesel and electric power in farming. In both examples, she shows how the social and economic importance of work that had been in women's domains was devalued or displaced.

Benston (1988) examines how language is shaped by our technology. She posits that since technology has been almost exclusively a male domain, our language may express well the ideas of the men in power, but may be altogether inadequate to express the issues that command the interest of women. Keller (1985) has researched the social construction of "the feminine," "the masculine," and "science." She shows how Plato and Bacon defined science and the processes of science in sexual terms. She also shows how the concepts of objectivity and subjectivity are bound up in these definitions, thus supporting the oppression and exclusion of women. For instance, woman is associated with nature, nurturing, and submission, while man is associated with the mind, control, and domination. Nature, which is to be mastered, is referred to as "she;" the scientific mind, which is to dominate, is referred to as "he." Woman is seen as "other" to man. Thus a woman in the sciences must undergo something of a personal crisis to resolve the conflict between the defining sexual metaphors of science and her actual sex as a human being practicing science. She must either deny her own femaleness or she must deny some other assumptions about what science is and how it is done.

Just as the notion of objectivity seems to be an elusive tenet of the scientific method, there is no one well-defined feminist standpoint. The research of feminists who are interested in technology in its various relations to women is as varied as are the researchers' own intellectual interests and training. The feminist research I have discussed in the second part of this paper employs the alternative methods of literary criticism and historical interpretation to inquire into these relations from feminist standpoints. The knowledge thus constructed embraces the value of the feminine. Our knowledge of the meaning of "objectivity" may be changed as a result. Our knowledge of the value of some of our technologies may be changed. The political nature of our knowledge of ourselves and our technologies comes into view. These are some of the results of assuming a feminist standpoint.

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WHY CONSTRUCTIVIST CLASSROOM PRACTICE CAN INCREASE PARTICIPATION OF WOMEN AND PEOPLE OF COLOR IN SCIENCE

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We have been struck by the consonances between aspects of constructivist classroom practice and the kinds of instructional strategies that have been found of advantage to female students and students of color in intervention programs in science. Since we have already examined consonances between a constructivist view of science and a constructivist view of science teaching and learning (Reeves and Ney, 1992), we can display in a matrix the striking parallels among all three positions: constructivist science, constructivist teaching-and-learning, and constructivist strategies for promoting inclusiveness in science teaching-and-learning (see table, following pages). Here we set out briefly our understandings of the three positions, arranged to emphasize how the various dimensions correspond to the perceived needs of female and minority students that have been documented in the literature. Most intervention programs and many proposals for science education reform in general are ad hoc and lacking in theoretical framework. Being constructivist means being self-aware about knowledge construction in science and in science teaching-and-learning, and in this paper we endeavor to provide such a framework. As von Glasersfeld has written,

> Good teachers...have practiced much of what is suggested here, without the benefit of an explicit theory of knowing. Their approach was intuitive and successful, and this exposition will not present anything to change their ways. But by supplying a theoretical foundation that seems compatible with what has worked in the past, constructivism may provide...less intuitive educators an accessible way to improve their methods of instruction (von Glasersfeld, 1989: 130).

The central argument of our earlier paper is still central here: the most effective teaching-and-learning is achieved when there is a coherence, rather than a disjunction, between what we communicate to students about learning by what we teach and what we

communicate to students about learning by how we teach. The most effective teaching-and-learning is achieved, in other words, when there is a coherence between the constructivist view of the science that we teach and the constructivist view of teaching-and-learning itself. Kenneth Bruffee highlights the negative consequences of a disjunction between constructivist science as practiced and the positivist way science is taught: the "heart of the problem" of declining enrollments in college-level science courses is "the tension between the way scientists do science and the way they tend to teach science," contrasting the active, interpretive construction of science in research with the static, museum-like exhibition of facts in science as taught (Bruffee, 1992: 20; cf. Ziman, 1968).

This consideration of how we may best intervene to increase participation in science leads us also to consider the broader question of why we intervene, and moves us from the instrumental to the contextual--to the values issues. What are the purposes of intervention programs? Whom do they benefit, and how do we conceive that benefit? The move from instrumental to contextual is comparable to the move from the question "How do we teach science?" or "How do we do science?" to the question "Why do we teach science?" or "Why do we do science?" The inquiry is value laden not least because it asks why (and how) are science and science teaching-and-learning exclusionary, why and how did they become so, and why and how do we make them inclusive.

We believe this paper gathers a more diverse yet more complete skein of threads to bring to the loom of inquiry than others. The literature of which we are aware brings together at best elements of only two of the three aspects of constructivist science, constructivist teaching-and-learning, and features of successful programs for women and/or minority students. Sue Rosser, for example, links feminist pedagogy to science, which for her is constructed knowledge, but she does not talk about constructivist learning theory (Rosser, 1990). Others link collaborative learning, an important dimension of explicit constructivist classroom practice, to greater involvement and success and improved performance for women and minority students, but the link to a constructivist view of science is absent, as is usually even the link to an explicitly constructivist classroom practice (Clewell et al., 1992; Gill 1991). Some work on incorporating diverse learning styles makes a similar point, but again the thread of science is absent (Clewell et al., 1992; Anderson and Adams, 1992). Most reporting of what works in successful intervention programs for female and minority students in science does not connect explicitly either to the more general issue of constructivist classroom practice or a constructivist view of science (Alper, 1993; Travis, 1993). Most literature on constructivist teaching-and-learning in science omits the thread of science itself as both a personal and a social construction, or the differential effects on women or minority students, or both. Finally, literature on the reform of college science teaching rarely makes explicit connections to any of these issues, although many specific elements of reforms, such as collaborative learning, active engagement of students, and the recognition of the importance of context not only of the classroom but also of the reform itself, are implicitly constructivist (Tobias, 1992).

WHY CONSTRUCTIVIST CLASSROOM PRACTICE CAN INCREASE PARTICIPATION OF WOMEN AND PEOPLE OF COLOR IN SCIENCE

Barbara J. Reeves and Cheryl Ney

	CONSTRUCTIVIST SCIENCE or "SCIENCE-PRACTICE"	CONSTRUCTIVIST TEACHING-AND-LEARNING	CONSTRUCTIVIST STRATEGIES TO PROMOTE INCLUSIVENESS
KNOWLEDGE	knowledge constructed by people who happen to be scientists	knowledge can be (re)constructed by students	create climate of expectations for participation and achievement on part of all students (not remedial) (Clewell et al., 1992; Kahle, 1990)
	knowledge constructed by scientists for reasons	knowledge constructed for their own reasons	encourage them to construct knowledge for their own reasons (Rosser, 1990; Jetter, 1993)
	knowledge contextualized	connected to their own lives, other school subjects, experiences, social issues	validate connections students make between science and personal experiences (Rosser, 1990; Clewell et al., 1992)
	knowledge as representations/models which have limitations (not "Truth") and which can be changed	constructed knowledge provisional, not absolute	validate alternative approaches, subjects, methods; ground models in experience (Sjøberg&Imsen, 1988; Rosser, 1990)
CONDUCT	many approaches, dependent on field and context (not unique "scientific method")	many teaching and learning styles	respect and validate different learning styles (Clewell et al., 1992; Anderson & Adams, 1992)
	observation theory laden, dependent on perspective	observation dependent on models being used, on personal perspective(s)	attend to how students are experiencing observation and hands-on activities (Rosser, 1990; Kahle & Rennie, 1993)

	knowledge constructed using community/personal resources, including accepted science, analogies, metaphors, and language generally, mathematics, models, instruments, money	students invent own analogies, use own language	use nonsexist, nonracist language and analogies, metaphors, alternative examples not specific to white middle class male experience (Sjøberg & Imsen, 1988; Rosser, 1990)
	communication through publishing, lecturing, and poster sessions	communication of understandings	emphasize speaking/writing about science, rather than problem-solving techniques and right answers only (Tobias, 1992; Corey et al., 1993)
	socialization process for newcomers	self-awareness of teachers and students as science teachers-and-learners	respect and take account of differential socialization of each student (Rosser, 1990; Clewell et al., 1992)
CHARACTER	theories and practices value laden	values of students incorporated into constructed knowing	make values explicit--system is constructed, not inevitable (Sjøberg & Imsen, 1988; Rosser, 1990)
	subject/object distance and subject/subject relatedness	students construct relations with subject/object of study	use interactive approaches to promote relating between student and subject/object of study (Rosser, 1990)
	creative, inventive, interpretive	students can create, invent, interpret	validate students' ideas, proposals (Clewell et al., 1992; Corey et al., 1993)
	collaborative, less competitive and hierarchical	collaborative teaching and learning, multidirectional and interactive	emphasize more how students learn than how to teach; use collaborative learning, study groups; make less competitive (Kahle, 1990; Clewell et al, 1992)
	responsibility, individual and collective	responsibility for learning of all, stake in success of all	incorporate peer support, peer teaching, and mentoring; counter image of teacher as expert (Clewell et al., 1992; Matyas & Dix, 1992)
	science as one set of perspectives	understanding how to construct science perspectives and to use them when appropriate	respect and value different perspectives; alternative sciences (Rosser, 1990)

It is worth noting that most intervention programs are designed to be supplementary to the regularly scheduled school experiences of the target groups of female and/or minority students, whether at elementary, secondary, or college level. While many programs have instructional components which are specifically of interest here, they rarely address teaching and learning experiences in ordinary classrooms, that is, they rarely address structural reform (Matyas, 1992). However, research about ordinary classroom experience points in the same direction, whether investigating science teaching styles that have differential impacts on male and female students, or proposing classroom strategies that are known from other contexts to advantage women or minority students (see Kahle, 1988 and 1990; Sjøberg and Imsen, 1988; Carter, 1990; Corey et al., 1993; Kahle and Rennie, 1993).

The view that science is a constructivist enterprise--that science is constructed knowledge--is neither new nor particularly problematic among reflective scientists or scholars in science studies (Gould, 1989; Knorr-Cetina, 1981; Collins, 1985; Latour and Woolgar, 1986). We have called this constructivist view "science-practice" (Reeves and Ney, 1992) by analogy with Arnold Pacey's "technology-practice" (Pacey, 1983). The term "science-practice" focuses attention on the combination of knowledge, conduct, and character of science: namely on the collaborative and individual activities involved in the creation, development and validation of scientific knowledge, interacting with the values and qualities that shape those activities and that knowledge. "Science-practice" also focuses upon the people called scientists, who are constructing this knowledge using all the resources available to them, including accepted science, metaphors and analogies and language generally, the language of mathematics, representations, models, instruments, financial resources, and personal experiences and values. People engage in science for various reasons, which may include curiosity, the search for what they understand as simplicity or regularities in natural phenomena, availability of funding in particular areas, the perceived prestige or promise of a field, the enthusiasm of a certain teacher, the desire to contribute to the social welfare, and so on. These reasons provide a context for the scientific activity. While science-practice can be competitive, the competition increasingly arises between groups or institutions, and most of a given individual's work is undertaken in collaboration with colleagues, rather than in direct competition with other individuals. This view of science-practice says nothing about who should or can do science, with the implication that anyone can. The fact that it has been done in the past mostly by white males says nothing about the future (Keller, 1992).

Recent research in teaching and learning in all fields emphasizes that learning is most successful when the students are actively and cognitively engaged in constructing and reconstructing their own understandings (Osborne and Freyberg, 1985; Driver, 1988; Gunstone, 1988; von Glasersfeld, 1984, 1989, 1992a, 1992b; Cheek, 1992; Tobias, 1992). Students do not come to science classes as empty containers into which the teacher pours information. They come with their own preexisting conceptions about thinking and about thinking scientifically, as well as about the science topic in question that they have already constructed on their own from their own previous experiences in and out of school. They have constructed this knowledge using familiar language, analogies, and metaphors. Successful science learning may require them to reconstruct that knowledge by making new language, analogies, and metaphors their own. Constructivist learning theory recognizes and

respects the humanity of the students, who are never regarded as disembodied minds that either can learn anything at any time or, if they do not or cannot, have some deficiency in need of remediation (Belenky et al., 1986). Because learning is an active, interactive process, students collaborate with each other and the teacher in identifying problems, proposing questions, comparing ideas, considering responses, evaluating different interpretations (including their own preconceptions), and reaching consensus--hence our term teaching-and-learning. The teacher does not deliver information, venerate content, or control the classroom but facilitates these interactions in order to foster the students' constructions and reconstructions of their own schemas (Hassard, 1990; Yager, 1991).

Successful intervention programs on behalf of female students and students of color respect what each student brings to the classroom, expect participation and achievement, and offer steady assurances that students are capable and do belong, in effect creating places where students can feel comfortable and valued, and where they can work at their own knowledge constructions and reconstructions (Clewell et al., 1992; Travis, 1993). Reviews of research and proposals for reform point in the same direction (Kahle, 1990; Rosser, 1990; Tobias, 1992). Virtually every study recommends development and use of collaborative learning situations, in classes and outside in study and problem-solving groups (see Johnson, et al., 1991, and references therein). These not only enhance students' learning through feedback from questioning and explaining to each other, but also provide peer support, consideration of the perspectives of others, negotiating skills, involvement in developing and attaining group goals, and sharing responsibility for each other's learning (Clewell et al., 1992. Increased opportunities for speaking and writing science (in explaining to each other and in journals, for example) enhance students' use of analogies and metaphors from their own experiences, and display and validate alternative modes of talking and understanding science. Although we are focusing on science rather than mathematics in this paper, we must mention the Algebra Project, which teaches mathematics to inner-city and rural children of color by means of activities growing out of their own lives and experiences (Jetter, 1993). In these ways students come to know themselves as scientific or mathematical knowers, and become more confident in their knowledge constructions and reconstructions.

Scientific knowledge in the constructivist view does not consist of facts, information, or "objective knowledge," or even less of "Truth" with a capital "t," but of effective or adaptive representations or models, or "viable explanations," which are of course human inventions (von Glasersfeld, 1992a and 1992b; Wheatley, 1991). Constructivists do not claim that scientific knowledge tells us anything about "reality," or about how the world "really" works. Such knowledge simply allows us, to the extent that we believe it, to operate effectively in the worlds of our experience. If the effectiveness of knowledge in a particular area appears to diminish, some scientists may try to reconstruct the knowledge to improve its operational effectiveness. Experimental findings are only more or less convincing to people, never crucial. What the features of "the world out there" "really" are is a matter of social consensus among scientists about which representations are viable at any given time; that situation can change and has changed many times in history (Collins and Shapin 1989). The terms "effective" and "viable" properly imply uncertainty and ambiguity in the knowledge itself, a topic that clearly needs explicit attention, especially in connection with the issue of

the grounds for belief in science, given the widely-discussed "crisis of legitimacy" in the sciences (Bruffee, 1992).

Constructivists thus suggest that there are many approaches to doing science, varying by field and context, because people differ in the values and conceptions they hold and the resources they choose to deploy. It thus makes no sense to talk about a single, rigid, recipe-like scientific method, as Project 2061/Science for all Americans also reminds us, insisting that "there simply is no fixed set of steps that scientists always follow, no one path that leads them unerringly to scientific knowledge" (Rutherford and Ahlgren, 1990: 5). Scientists choose to observe what they observe because they "see" through the lenses of the theoretical concepts and constructions of their fields, that is, from a certain perspective which has been developed over time, through the intellectual and social processes of their education and the practices of their disciplinary community, filtered through their own inclinations and interests (Hanson, 1958). Furthermore, science-practice--knowledge, conduct, and character--is value laden. It incorporates the values of individuals, of communities of scientists, of the institutions that support science, and of the larger society in which it is embedded.

Constructivist science teaching-and-learning emphasizes the processes of developing/constructing understandings or representations of natural phenomena and the tentativeness of that knowledge. Bruffee argues that college and university students at least "should be learning collaboratively how scientists confront the uncertainties and ambiguities of science by collaboratively constructing, interpreting, manipulating, and calibrating scientific models and symbol systems" (Bruffee, 1992: 21). Such an approach makes it clear to students why models or representations are constructed, how they are tested for reliability, and how they become accepted by the relevant scientific community and become "true." Bruffee (1992: 21) suggests that the constructivist approach may change the kind of students who become science majors from those who want to exhibit skills in reaching right answers and to avoid loose ends to a more adventuresome group who want "the intellectual rewards and excitement of trying to cope with uncertainty, ambiguity, and a world full of loose ends" but have been seeking those challenges, as Sheila Tobias's informants had, outside of science in the humanities and social sciences (Tobias, 1990).

At both college and school level, understanding the tentativeness of science knowledge constructions allows students to develop more confidence in their abilities to construct and reconstruct this knowledge for themselves. It also validates their own prior efforts at meaning-making, even if these conceptions are not the ones currently held by scientists. Constructed knowledge incorporates values, providing context for learning to students; they can articulate reasons for being interested in a particular subject that make sense in their own personal situations. The constructivist classroom can also encourage students to confront their worries about studying a particular subject, so that they can indeed take responsibility for their learning.

Constructivist teaching-and-learning respects the variety of ways people construct knowledge, and hence incorporates many teaching and learning styles. The teacher is a facilitator of students' learning by asking leading, probing questions, responding to questions

with further questions, and choosing appropriate experiences for the students to grapple with. These approaches contrast sharply with the teacher as deliverer of information, transferring it into student minds, where it sits passively until regurgitated on an examination. The variety of student learning styles is well known, and the constructivist classroom respects them by incorporating activities, experiences, and modes of assessment that facilitate rather than hinder students' learning and demonstration of understanding (Anderson and Adams, 1992; Parker and Rennie, 1992). Students have preconceptions not only about scientific topics but also about appropriate teaching and their own learning; the older they are when they first encounter constructivist approaches, the more resistant they may be to thinking that they are being taught properly or that they are learning (Gunstone, 1988). Constructivist approaches can facilitate students' reflection on their own cognitive processes and what it means to create knowledge (Gunstone, 1992; Larochelle and Désautels, 1992).

Intervention programs typically employ activities, experiences, and teaching strategies designed to strengthen and enhance the self-confidence of female students and/or students of color for whom they are organized (Matyas and Dix, 1992; Clewell et al., 1992). Research with upper elementary teachers and students in Australia and the US indicates that inservice workshops on gender-equitable teaching techniques for teachers enhances for their female students their enjoyment of and confidence in their ability to do science (Kahle and Rennie, 1993). In addition, to counter the common situations where previous experiences have appeared to advantage male students in traditional classroom teaching, provision of opportunities for hands-on experiences and activities and attention to how students are experiencing the objects, ideas, and processes involved likewise enhances the confidence of female students in their ability to succeed at science (ibid.) Traditional science teaching tends to be aimed at a narrow range of learning styles and is widely recognized as being ineffective for many students (Tobias, 1990; Adams, 1992); teaching for diversity and inclusiveness respects the wide range of student learning styles and incorporates a suitable variety of activities, experiences, and modes of assessment (Anderson and Adams, 1992; Parker and Rennie, 1992).

Science has been gendered masculine (Keller, 1985 and 1992; Kahle, 1988; Sjøberg and Imsen, 1988; Martin, 1989; Thomas, 1990; Vetter, 1992); in our culture it also connotes middle class and white. Gender, class, and race differences pervade our society, and it is not surprising that they are pervasive in education as well. Constructivist teachers need to become aware of the possibility of sexist, classist, and racist behaviors in the classroom, and to be comfortable with and employ gender-, class-, and race-equitable teaching strategies. Not every constructivist practice is inclusive. It is well known that white male students on average get more and higher quality attention from teachers, who also have higher expectations for their academic performance; the situation might well remain the same in a value-laden constructivist classroom, unless teachers make themselves aware and open to change. In one study, both male and female teachers graded science examinations higher when they were attributed to male than to female students (Spear, cited by Kahle, 1988). Science textbooks picture very few women or people of color and cite the work of even fewer. Motivational sections in textbooks rarely take account of known gender differences in students' concerns. One could go on and on (for references see Kahle, 1988 and 1990;

Sjøberg and Imsen, 1988; Rosser, 1990). Schools traditionally have simply reproduced these inequities rather than transforming themselves into change agents. And intervention programs have developed as supplements, remaining marginal and rarely evolving into structural reform.

The only comforting aspect about this grim recitation--even grimmer had we considered in detail the Eurocentric nature of science--is that from the constructivist perspective the gendered and Eurocentric character of science is in fact a social construction and not an inevitable consequence of some "law of nature." Once we recognize the social, cultural, and historical nature of that construction, we can recognize that other cultures have scientific traditions that are not inferior to the West's but different (Rattansi, 1989; Sélin, 1992), and we can see that gender or race differences in participation in science have not arisen because of inherent deficiencies in women or people of color but because the dominant white male culture constructed the norms, values, practices, and knowledge of science predominantly in its own image. Recognition of this constructed nature of science not only can empower women and people of color to cope with science-practice as it operates at present, but also it can enable them to consider, and perhaps even to create, alternatives that can enrich science (Barinaga, 1993a and 1993b; Keller, 1985 and 1992).

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FROM HOSTILE EXCLUSION TO FRIENDLY INCLUSION: TRANSFORMING THE COLLEGE SCIENCE CLASSROOM

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At the 8th National STS meeting and Technological Literacy Conference (Jan. 15-17, 1993), we discussed two programs aimed at transforming university science courses: The University of South Carolina System model project aimed primarily at changing teaching strategies to recruit and retain women in the science fields (see Rosser, 1993, in this volume) and the Indiana University of Pennsylvania (IUP) project to institute changes in both the science curriculum and pedagogy to create a more hospitable learning environment. Both projects have workshops as an important component (1) to introduce science faculty to research findings in Women's and Ethnic Studies which apply to the teaching of science, mathematics, and engineering to produce pedagogical transformations, (2) to foster cooperation among diverse science and mathematics faculty to show that science, at its best, is a cooperative and multidisciplinary venture, and (3) to develop innovative courses, teaching styles, and diverse course materials which seek to attract more students to participate in science.

The Problem:

National attention has focused on three inter-related problems of science in the U.S.: widespread scientific illiteracy, the need for more American scientists and engineers, and the

under-representation of women and men of color in the sciences. Any shortage of scientists and technologists which this country may face in the next century and the under-representation of some groups in science are inextricably linked with the degree of science illiteracy. As Tobias (1990) says "science is too little 'spoken' in the nation's households and there are too few role models for young people to emulate."

The problem of widespread scientific illiteracy among even educated Americans has been addressed by both academics and the popular press. Even using the simple criterion of defining scientific terms, Miller (1988), for example, finds that only 3% of high school graduates, 12% of college graduates, and 18% of PhDs qualify as scientifically literate. This lack of scientific literacy goes beyond failure to recall once-learned scientific terms or principles; most Americans lack the fundamental intellectual skills or insights to appreciate how science affects their daily lives (AAAS, 1990). Because many Americans feel that science is incomprehensible to them, they are either afraid of or hostile to science. If we as a nation are to attract more Americans to study science, then we must attract part of the "85% cohort" (Sigma Xi, 1990) or the "second tier" (Tobias, 1990) to careers in science, technology, engineering and mathematics in addition to the "15% cohort" which is already interested in science.

Although there are questions about the magnitude of the shortage of American scientists and engineers for the 21st century (Holden, 1989), it is clear that the number of Americans studying science has decreased in the past 20 years. Now more than 50% of the graduate degrees in science and engineering are earned by foreigners (DePalma, 1990). The concern which is most often expressed in science literature (Powledge, 1989, speaks of "more than 300 recent reports from prestigious organizations") is the necessity of training

more of the American "best and the brightest" in the science and technological fields. This so-called "15% cohort" of freshmen expect to major in the sciences (Sigma Xi, 1990). Only fifty percent, however, of this "15% cohort" complete a major in science (Sigma Xi, 1989). To make up for this predicted shortfall in American scientists and engineers, whatever the magnitude of that deficiency, women and men of color, the traditionally under-represented groups in science, must be attracted to science and technical careers.

How can we attract more women to major in science, math, and engineering when over 70% of the women who start out in these majors do not graduate in those fields (Hewitt and Seymour, 1991)? The attrition rate of women majors in science is nearly double that for science majors as a whole. Even though women earn 40% or more of the undergraduate degrees awarded in this country and even though more women up to the mid-1980s (Office of Technology Assessment, 1985, National Science Board, 1989) went to graduate school in the natural sciences and engineering, they earn 16% of the doctorates in the physical sciences, 10% in computer science, and 7% in engineering (Holden, 1989). Because of these attrition rates--women leave their science majors at both undergraduate and graduate levels--it is not surprising that women are under-represented in the science/technology workforce. Women scientists and engineers made up about 13% of the science/engineering workforce in 1986 (National Science Board, 1989); their participation varied greatly by field such that women were 4% of the engineers, 25% of the mathematicians, 40% of the psychologists as examples. Cultural gender-stereotypes and discrimination in academia and the workplace are probably most responsible for these differences in fields, with women under-represented in engineering, physics, chemistry, geology; well-represented in health sciences, psychology, and mathematics; and over-represented in nursing and occupational and

physical therapy. These gender-stereotyped career expectations are difficult to overcome, but they can be changed through mentoring programs in K-12 (Sutton, 1988).

From the mid-1980s to the present, the number of American women who earned science and engineering degrees remained about the same--even at a time when national attention was centered on recruiting women into technical fields (Brush, 1991). We can explain part of this plateau in the number of women staying in or entering science in terms of how science is taught and envisioned. The high attrition rate of talented women science majors indicates that attitudes and pedagogies in the college science classroom are hostile to women. The way in which science is taught is also hostile to other groups, because only 50% of science majors graduate with science degrees.

Feminists have raised other reasons for concern about the scientific illiteracy of women and the attrition of women in science. Careers in science represent important achievement and financial opportunities which have been denied women; dropping out of the math and science courses also handicaps girls and women from many other potentially fulfilling and financially lucrative positions (National Research Council Committee on Women in Science and Engineering, 1991). Thus, the retention of women in science is part of a larger goal of gender equity. We are also concerned that talented and enthusiastic girls and women may not be receiving the same support, encouragement, feddback and training that their male counterparts receive (AAUW, 1992). A womanless science is more likely to contain gender biases, and to "discover" facts and findings that are used to justify discrimination against women (Harding, 1986, 1991). Finally we are concerned that without sufficient background in the sciences women will not understand the ways in which science impacts on their lives, and will not be able to use scientifically based information to make

important life decisions (Bleier, 1984, 1986). At the national level we need women trained in all scientific fields to contribute to important policy decisions (Harding, 1986, 1991)

These three problems in science and science education in the U.S. are inter-connected. By improving the ways in which we teach science at **the college level** we can reach more groups of students who have previously felt excluded from science. As Tobias (1990) says it is too easy college professors to blame the K-12 educational system and K-12 teachers for the lack of entering first-year college students who are interested in science. It is the college professors' responsibility to "grapple with . . . how to recruit, teach, reward, and cultivate different kinds of students to science, students who are not younger versions of" ourselves (Tobias, 1990). By reaching more students, we create a better understanding of science by people both within and without science. As more diverse people are attracted to study science, science becomes "better" in that different viewpoints and different areas of interest expand science's horizons. An important case in point is how primatology was transformed through the participation of women primatologists (Hrdy, 1984; Haraway, 1991).

The most important potential impact and significance of our changing the science curriculum at IUP is the possibility of stemming the loss of students from science majors. The high rate of women abandoning a major in science, which is part of the national trend, occurs also at IUP (and at our sister institutions in the PA State System of Higher Education-SSHE). IUP's undergraduate student body is approximately 55% women and 45% men. In the undergraduate non-science major courses women students are well-represented in such departments as biology, chemistry, physics, and mathematics. Closer analysis (Richardson, 1990) reveals that they are primarily in courses required for such majors as nursing, food

and nutrition, and respiratory therapy. The percentages of women majoring in these health-related fields hover at more than 90%. Women students are over-represented in psychology where they made up 60-80% of the graduating seniors (1980-1990). The percentages of women students graduating with degrees in computer science, geoscience, and physics are low--usually quite far below the national averages. For IUP Master's degrees the under-representation of women in science worsens. In biology, for example, in which women earned from 30 to 55% of the BS degrees from 1980-1990, the women who earned biology Masters degrees are less than 15% of the total. From 1983 to the present more Masters degrees in psychology were awarded to women than to men. For the other science departments, women graduate students are even scarcer than they were as undergraduates. Again, unfortunately, these trends at IUP reflect national trends where attrition rates of women from graduate school are even greater than attrition rates of women undergraduates (Ehrhard and Sandler, 1987). What we see at IUP is mirrored by other SSHE universities.

The greatest potential impact resulting from our work would be a decrease in the loss of students who started out as science majors. We hope to significantly increase the number of students who continue in science. Additionally, we hope to attract students to a career in the sciences and to impact positively upon students' understanding of science's role in their personal lives, in society, and in the environment.

In a series of articles and books (e.g., Rosser 1986, 1990) Rosser has examined the issue of gender bias in both the practice and the teaching of science, and has made a series of concrete suggestions for improving our curriculum. In Female Friendly Science (1990) she explains the relationship of concrete specific suggestions to theoretical models of women's ways of knowing (Belenky, et al., 1986) and to models for curriculum transformation.

Rosser contends that incorporating her suggestions will not only make science and math classrooms female-friendly, but will also appeal to people of color and white males. For example, Rosser (1990) recommends the elimination of sexist language and discriminatory classroom behaviors as a way of enhancing women's participation in science. She also presents an extensive list of concrete suggestions designed specifically for the natural sciences and laboratory courses. Some of these suggestions are:

- Expand the number and kinds of observations beyond those traditionally carried out.
- Accept the personal experiences of women as a valid component of empirical research.
- Use examples and exercises that explore problems of social concern and discuss practical uses of science.
- Formulate hypotheses focusing on gender.
- Use a combination of qualitative and quantitative methods.
- Use a variety of methods or a multidisciplinary approach.
- Use more interactive and less competitive methods.
- Emphasize the integration of science with other aspects of life.

Our work also integrates the methods for teaching espoused by the AAAS report. These suggestions are similar to those of Rosser (1990) and are believed to be particularly effective with regard to both women and people of color. These methods include the following:

- Employ pedagogical techniques that make students aware of their commonsense beliefs which can be tested empirically.

- Conduct research that is more congruent with how science is actually practiced. The ideal is for students to conduct original research.
- Design group work.
- Have students prepare written reports and have them critically reviewed by peers.
- Allow students direct experience with data derived from the natural world.
- Use original materials.
- Utilize collaboration and cooperation to help students develop logical arguments and to learn how to evaluate evidence.
- Use alternative assessment strategies.
- Raise questions about science in everyday life.

Description of the Project

This review suggests that there are many similarities in the suggestions developed by different authors and associations addressing different concerns within science education. The recommendations of AAAS for addressing scientific literacy, of Rosser for gender balancing the sciences, and of NSF and others for recruiting and retaining future scientists all emphasize the need to change the college curriculum and to make the educational climate less hostile and more friendly.

The Project Staff. We are a team of female faculty from the College of Natural Sciences and Mathematics at Indiana University of Pennsylvania (IUP). Formerly a state teachers college, IUP is now a state university; it is the largest of the fourteen universities in the State System of Higher Education of Pennsylvania (SSHE-PA), and the only one to award doctoral degrees. IUP is Pennsylvania's fifth largest university with a current enrollment of 14,000 students. Although there are students from nearly every state and from 60 foreign countries,

most students are from Pennsylvania, many from the immediate area.

As a team we have been working in the area of women in science since Sue Rosser's initial visit to campus in 1987. We received funding from the state system to conduct a semester long program on Women in Science in 1989. The program was oriented towards gender-balancing the curriculum and included a faculty reading seminar, a colloquium series, a film series, an external speaker (M. Patricia Hynes), and a one day faculty conference. Since then we have continued our efforts to transform the curriculum through campus, regional, national and international presentations and workshops. In addition to our programs, there have been college-wide meetings to assess faculty interest in recruitment and retention projects.

Phase I. The proposed project involves two phases. In Phase I (year 1) two courses will be developed (Summer 93) and taught (Spring 94) following the AAAS (1990) guidelines for radical curriculum revision of science courses and following Rosser's (1990) concrete suggestions for creating a more inclusive classroom environment. In Phase II a one-week workshop for ten IUP faculty will be held in Summer 94 for them to transform introductory science courses for AY 94-95. In AY 95-96 we plan to hold a two-day conference on efforts to recruit and retain students in science.

"User Friendly Science" is a first-year, non-laboratory science elective which examines women's and minorities' contributions to, exclusion from, and potential to transform science. This interdisciplinary course aims to empower the non-traditional science student to continue in science, to attract more students to science, and to enlighten the non-science major. The course content and pedagogical styles will actually encourage and sustain all science students. "History of Science: Different Views of the Natural World" will reach

first and second year students, especially the science major. This course explores the relationship of scientific knowledge and societal context. Both courses employ pedagogical innovations to the science classroom such as: group work, alternative assessment techniques, peer review, use of original materials, and student development of original (or alternative) hypotheses. In Phase II (years 2 and 3) ten IUP faculty will be trained to conduct exemplary introductory laboratory courses based on the recommendations of Sue Rosser (1986, 1990) and Ezra Shahn (1990, 1991, Bennick et al., 1990).

"User Friendly Science" looks at science as a process and not solely as a collection of facts or conclusions to be memorized. It will be divided into four parts: I. What is science? This portion includes stereotypical views of science and scientists, what scientists do and how science is accomplished. Students will appreciate that how we teach science is far different from the practice of science. II. History of women and men of color in science covers obstacles to their success and their accomplishments. Students will note some commonalities in the experiences of women and men of color. III. Feminist critiques of science includes criticisms of the methods, practice, and use of science. Once students learn about one critique of science, they become aware of how other biases, e.g., race, class, sexual preference, religious beliefs, may distort theories and conclusions drawn from experimental or observational data. IV. Modifications in the teaching of science and labs to encompass more students' attention and styles of learning are reviewed. It is important for students to consider some of the following: why some questions in science are pursued and others ignored, who are the people asking what questions, what types of projects are funded by internal and external grants, why scientists have authority and are considered experts by the media, what leads to fraud in science and the frequent failure of science to police itself.

At the end of the course Tobias's (1990) question will be asked of the students: why do talented, qualified students choose not to do science? Students will synthesize all they have learned, read, and pondered to answer that question and to come up with suggestions that will change the way science is taught and strategies to "woo" more students to science. Readings include Tobias (1990), Rosser (1990), Tuana (1989), Bleier (1984, 1986) and many journal articles.

This course will not be taught in the traditional lecture mode with the professor spewing fountains of facts, figures, and final conclusions. This course examines the processes of science. The professor is a guide, a leader at times, an exemplar of clarity of thought and expression, a coach in encouraging the hesitant student, and a teacher of the intellectual skills necessary to comprehend the material and write about it. Writing forms an important part of this course unlike most introductory level science courses. The writing takes various forms: short essays, tests, short papers, in-class writing, out-of-class writing, ungraded and graded writing, peer-evaluated papers, papers which may be revised, and so on. It is very important that students develop their writing skills so they may communicate how they followed a particular line of reasoning to its conclusion. Essays which require description, explanation, analysis, and synthesis hone the critical thinking skills of students. Some writing, such as the keeping of a journal, permits students to interact more intimately and indirectly with the ideas presented in lecture, readings, classroom discussions, and so on. Writing in a journal is one way in which students' personal experiences may reiterate what they read/learned. Again, unlike most introductory level science courses, this course has ample opportunities for revision of student work.

The main goal of "History of Science: Different Views of the Natural World" is to

develop an understanding of the differences between perceived workings of science versus how science really works. Most students think scientific discoveries are always well-planned, follow an easy, step-by-step method, and the anticipated results are always correct. They will be introduced to the problems, unexpected results, surprise, joy, disappointment, rejection by other scientists and society which have been faced by scientists. Students will replicate some important historical experiments, such as those of Newton and Galileo, in order to gain an understanding of the processes of science. Additionally, students will think of other ways of approaching the same question (example, gravity) and will devise their own experiments working collaboratively in small groups. Thus they can learn how important intuition and accident as well as critical thinking and analytical skills are in science. In contrast to Newton and Galileo, icons of science, students will select a non-traditional scientist or science (example, Ellen Swallow Richards and chemistry in the home) and study that contribution to science and its level of acceptance. Both an oral and written report will be generated by the student's research. This course will include western and non-western scientific developments, contributions of women and men of color, in-depth studies of the mechanics of experimentation, past and present controversies in beliefs of scientific theories (plate tectonics or evolution, as examples), and investigations into the causes and nature of scientific fraud and deliberate perversions of observations and experiments. Books to be read include Brush (1988), Duschl (1990), Kass-Simon and Farnes (1990), Schiebinger (1989) and journal articles and original materials.

Phase II. The second phase (years 2 and 3 of the project) involves a one-week workshop during summer 1994 for 10 IUP College of Natural Sciences and Mathematics faculty where workshop leaders, Sue Rosser and Ezra Shahn, will help faculty transform their laboratory

exercises and revise their teaching styles to make science more approachable to more students. These outside experts are experienced in teaching interactive, interdisciplinary, and innovative courses in the sciences. The main activity of the week will be the collaboration of the team in the design and revision of the introductory science courses. Faculty will be responsible for developing instructional materials for a single course, but will cooperatively construct all courses and will peer review each other's plans. At this workshop they will modify their lab exercises and revise their syllabi. We have already targeted some introductory level science courses and professors for this workshop. The faculty includes those who have previously indicated interest in the recruitment and retention of women and minorities or gender-balancing in the curriculum. Over the summer, participants will refine their course syllabi, readings, course materials, laboratory exercises, and other assignments. At the end of the summer the group will reassemble for 1 1/2 days to discuss and critique the course plans.

Discussions at workshops such as this have proven very fruitful in instituting Liberal Studies synthesis courses and writing-across-the-curriculum at IUP. Indeed, we expect the discussions to contribute to a more unified, collective sense of purpose among the faculty involved. The courses will build upon and nourish a network of faculty interested in the issues of retention, recruitment, diversity, gender-balance, and scientific literacy. Faculty will be encouraged to invite their colleagues to participate in or observe their class activities. Faculty will agree to submit course materials, to cooperate with the evaluation component of the project, and to attend the follow-up conference.

Follow-up. Finally, in year 3 of the project we plan to hold a regional 2-day conference with representatives from IUP and the other 13 state universities to inform them about what

worked and what did not in changing our science curriculum. Other regional institutions, such as Penn State and Seton Hill College, would also attend. The day would consist of a keynote speaker and small workshops. As other SSHE universities have followed IUP's lead in revamping general education/liberal studies, so we hope they will follow us in this most important effort to revise and revitalize how we teach science. The enthusiasm and zeal of the "newly converted" may subvert traditional teaching styles. By retaining more science majors and attracting more talented, once science-avoidant students to our science classrooms, this core of enlightened teachers may act as a critical mass to transform more science courses.

Integration into Existing Curriculum

The current Liberal Studies Program at IUP, instituted in 1989, includes two types of science courses: the 4-credit lecture and lab science course and the 3-credit lecture science course. "User Friendly Science" and "History of Science: Different Views of the Natural World" would be added to the Liberal Studies program as 3 credit non-lab science courses. Students may select one of two options: either two 4-credit lab science courses or one 4-credit lab science course and two 3-credit non-lab science courses. Students may, of course, opt to take more science courses as "free" electives. The teaching of the exemplar science courses will involve faculty from across the College of Natural Sciences and Mathematics.

IUP is an excellent site for a curricular reform project in the sciences for the following reasons: 1) We have laid the groundwork for such a project by establishing the need for curricular reform in earlier programs, and by establishing a network of interested faculty on campus and across the State System. 2) IUP is a leading member of a State System allowing us to share our methods and results with faculty from thirteen sister

institutions, and a member of the newly formed Pennsylvania consortium of universities and colleges interested in assessing the effectiveness of recruitment and retention efforts. 3) The State System supports our efforts to improve and to gender-balance the curriculum. 4) The new Liberal Studies Program endorses the curricular changes envisioned and is also the occasion for the review and revision of syllabi and teaching methods. 5) The Faculty Professional Development Committee and the Center for Teaching Excellence also endorse and are working toward such pedagogical innovations.

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FROM HOSTILE EXCLUSION TO FRIENDLY INCLUSION: TRANSFORMING THE COLLEGE SCIENCE CLASSROOM

A PRELIMINARY REPORT ON THE NSF PROJECT FOR THE UNIVERSITY OF SOUTH CAROLINA SYSTEM

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National attention has focused on three interrelated problems of science in the U.S.A.: widespread scientific illiteracy, the need for more American scientists and engineers, and the under-representation of women and men of color in the sciences. Intervention programs have previously concentrated on enabling students (and faculty) from under-represented groups to "fit into" or "adjust to" the existing science system. A contrasting approach suggests that only changing the science curriculum and how science is taught in the college classroom will significantly affect the participation of all students in science. By increasing the number of students in science and by changing the ways in which science is taught, students will be more comfortable "speaking science." This presentation focuses on a description of and preliminary results from the NSF Project: University of South Carolina System Model Project for the Transformation of Science and Math Teaching to Reach Women in Varied Campus Settings.

Description of the Project:

This project is a two-year program that designs, implements, evaluates and disseminates a model for transforming the teaching of science and math in a variety of contexts, better to reach and retain women in science and technological careers. The compelling need for this program is demonstrated by the documented inadequate numbers of American-trained scientists preparing to meet our nation's needs in the 1990's, and the under-utilized potential of both women and minorities in the fields of science, mathematics and engineering. The project requires collaboration among the nine campuses of the University of South Carolina System which serves diverse populations throughout the state of South Carolina. The 25 participating science and math faculty come from five two-year campuses, three four-year, and one major graduate/research campus. Each faculty member attends ten days of intensive interactive workshops over a period of two years, and is in correspondence with the project during interim periods. The project includes two on-site two-day workshops at each of the nine campuses for the purpose of individualized design and implementation of the teaching model. Participants also attend three plenary workshops, each lasting two

days, for the purpose of inter-campus exchange, expert consulting, contrastive analysis, and synthesis of the most successful strategies. Each campus participates in the design and testing of the teaching model. When disseminated nationally to science and math faculty, this model will be adaptable to various types of institutions, enabling them to reach women in those places where they are most likely to be found, and then retain them when they are recruited to graduate/research programs.

Goals of the Project:

The project has five overall goals:

1) To encourage more women to enter science and math courses and to stimulate them ultimately to pursue science/technology careers, meeting a national need and improving women's access to more lucrative livelihoods.

2) To introduce science and math faculty to the body of research findings in Women's Studies that can apply to the teaching of science, mathematics, and engineering to produce pedagogical transformations that expand their effectiveness.

3) To improve cooperation among science and math faculty in diverse settings, not only that faculty of two-year campuses may learn from researchers of a graduate campus, but that the latter may also learn from the former how to improve the teaching of science and mathematics in ways that welcome and stimulate women.

4) To help science and math faculty focus on the value of diversity among students as a strength which leads to more innovative problem-solving.

5) To design a faculty development model easily adapted to a variety of institutions, and thus particularly useful to those with very large populations of women which tend to be very unlike traditional research institutes throughout the nation.

Objectives Associated with Goals:

1) To increase participants' knowledge of current research findings in Women's Studies regarding the numerous reasons that women are not more prominently represented in science and mathematics.

2) To assist participants in evaluating their present teaching approaches in light of the new knowledge cited above.

3) To improve the participants' ability to relate to their women students through varying teaching approaches and applications.

4) To develop teaching strategies and disciplinary applications tailored to each campus population and academic level, and based on the new knowledge cited above.

5) To establish a cooperative and mutually supportive network of faculty from the two-year and four-year teaching campuses and the graduate/research campus who share a commitment to increase the number of women entering and staying in math and science.

Current Status of Project:

At this point, the project has reached the halfway mark; funding for the project began January 1, 1992 and will run through December 31, 1993. After selecting project participants and staff and beginning to develop evaluation instruments, the first plenary conference for the twenty-five participants was held in May, 1992. During the summer and fall, 1992, eighteen of the twenty-five participants taught the course they are revising in conjunction with the grant. Each participant has received one site visit from the principal investigator and graduate assistant to discuss his/her progress with the project.

Applications from Female Friendly Science:

Particular emphasis has been placed upon encouraging faculty to consider suggestions from the book Female Friendly Science (Rosser, 1990) written by the principal investigator. The suggestions relate directly to the first three objectives of the grant:

- Expand the kinds of observations beyond those traditionally carried out in scientific research. Women students may see new data that could make a valuable contribution to scientific experiments.

- Increase the numbers of observations and remain longer in the observational stage of the scientific method. This would provide more hands-on experience with various types of equipment in the laboratory.

- Incorporate and validate personal experiences women are likely to have had as part of the class discussion or the laboratory exercise.

- Undertake fewer experiments likely to have applications of direct benefit to the military and propose more experiments to explore problems of social concern.

- Consider problems that have not been considered worthy of scientific investigation because of the field with which the problem has been traditionally associated.

- Formulate hypotheses focusing on gender as a crucial part of the question asked.

- Undertake the investigation of problems of more holistic, global scope than the more reduced and limited scale problems traditionally considered.

- Use a combination of qualitative and quantitative methods in data gathering.
- Use methods from a variety of fields or interdisciplinary approaches to problem solving.
- Include females as experimental subjects in experimental designs.
- Use more interactive methods, thereby shortening the distance between observer and the object being studied.
- Decrease laboratory exercises in introductory courses in which students must kill animals or render treatment that may be perceived as particularly harsh.
- Use precise, gender neutral language in describing data and presenting theories.
- Be open to critiques of conclusions and theories drawn from observations differing from those drawn by the traditional male scientist from the same observations.
- Encourage uncovering of other biases such as those of race, class, sexual preference, and religious affiliation which may permeate theories and conclusions drawn from experimental observation.
- Encourage development of theories and hypotheses that are relational, interdependent, and multicausal rather than hierarchical, reductionistic, and dualistic.
- Use less competitive models to practice science.
- Discuss the role of scientist as only one facet which must be smoothly integrated with other aspects of students' lives.
- Put increased effort into strategies such as teaching and communicating with nonscientists to break down barriers between science and the lay person.
- Discuss the practical uses to which scientific discoveries are put to help students see science in its social context.

Preliminary Project Results:

On January 7 and 8, 1993, the second plenary conference for the project was held. Considerable quantitative information from participant questionnaires, student questionnaires, and student performance and retention has now been collected and is in the process of being analyzed. Although the quantitative data suggest some interesting trends, those data will be more complete and reliable at the end of the project.

At this point, I prefer to share the following qualitative observations based on reports from faculty who have taught the revised course at least once:

1) All faculty found that the project enhanced their teaching. Even faculty who had not yet taught the revised course reported positive effects of information gleaned for the project which they were using in teaching their other courses.

2) Most faculty reported conscious attempts to include information about women in course content. Some used first and last names of scientists to dispel the stereotype that all scientists are male. Many rewrote word problems to include women, women in positive situations or examples from female experiences such as cooking.

3) All faculty reported they paid more conscious attention to insure equitable treatment of males and females with regard to eye contact, calling on students, and waiting for student responses to questions.

4) Most used group work or collaborative projects for the first time or more extensively than ever before. All but one reported that this was successful in increasing student learning. The students particularly enjoyed group work, although some resisted at first. Both faculty and students agreed that it improved student performance and learning.

<u>Specific Anecdotes</u>:

The following three examples given by faculty participants provide interesting results of the effects of the project on their teaching:

1) A mathematics faculty member who had been teaching for many years thought he made eye contact equally with both males and females in the class. A questionnaire he devised for students in conjunction with the project revealed that the students, particularly female students, thought he made more eye contact with male than female students and that he waited longer for males to respond to questions. Based upon this finding from the questionnaire he made a conscious attempt to make more eye contact with female students and wait longer for them to respond the next time he taught the course. The response of students on the questionnaire indicated their perception of his improved attempts, going from 3.79 to 3.91 (scale was 1 to 4) for eye contact, and 3.[illegible]5 to 3.96 in waiting adequate time for responses. Both are significant differences.

2) Another mathematics faculty member reported on her successful attempts at having the students form functioning out-of-class study groups by selecting the groups on the basis of when the students shared available time free from class, work, and family schedules. Although she had thought of these groups as being particularly

helpful to the female students, the male students reported more benefit from the groups. This finding was repeated in other classes although both male and female students with one or two individual exceptions always found the groups to be helpful.

3) A physics faculty member tried arranging groups with different gender compositions to explore the effects of gender on students' skill with the equipment in the laboratory. In two laboratory sections he set up four groups: one group included two males and two females; another included 4 females; and the other two groups included 4 males. In both classes at the end of the course, the mixed-gender group performed the best, with the all-female group performing only slightly less well (not a significant difference). The all male groups performed significantly less well on the skills test than either the mixed gender or female only group. Perhaps this finding reflects the substantial body of research demonstrating that coeducation benefits males but not females.

Conclusions:

Since the NSF Project: The USC System Model for the Transformation of Science and Math Teaching to Reach Women in Varied Campus Settings is only partially completed at this time, it would be premature to draw firm conclusions based on anecdotal qualitative and partial quantitative data. At this point in the project, preliminary data suggest that project objectives attempted thus far are being met. Specifically, faculty are increasing their knowledge of current research findings in Women's Studies regarding the reasons women are not more prominently represented in science and mathematics. They are evaluating their present teaching approaches to make them more female friendly in light of that knowledge. Preliminary evidence suggests that the project does improve the participants' ability to relate to all students, including their women students and thereby increase the retention of women in science.

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BREAST IMPLANTS AND THE CHALLENGE OF AN INFORMED PUBLIC

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From newspaper headlines to Nightline, complex, troubling issues related to the silicone breast implant controversy frequently flashed across public consciousness during the past two years. As the debate progressed, a classic case study took shape that gave concrete evidence of the extent to which biomedical knowledge and practice are eminently and irreducibly social and cultural. The medical profession claims that the theory and practice of modern medicine are grounded in, and governed by, the traditional ethos of science. Yet, in the glare of the silicone breast implant dispute, medicine devoted to cosmetic and reconstructive surgery presented itself as something other than a methodical, objective, dispassionate search for, and application of, knowledge and truth. In addition, the emotionally charged debate over the need, safety, and effectiveness of silicone breast implants sharply demonstrated how far health and illness can go beyond merely physical, biological states to being essentially what anthropologists term "culture-bound syndromes."

The complex and intractable aspects of the silicone breast implant case raise a host of interesting and fundamental issues. However, since this organization, the National Association for Science, Technology and Society, is "dedicated to empowering citizens to question, understand and guide the science and technology which surrounds and extends us," (NASTS, 1991) I want to use the debate over the safety of breast implants to exemplify some of the obstacles to achieving this objective. To do this, I will trace the history of the silicone breast implant controversy and the kind of information that was available to regulators, physicians, and consumers. I will then focus on the issue of choice which reverberated throughout every level of discussion on breast implants and the role of government agencies in protecting the public interest in scientific and technological matters.

Scientific Illiteracy and the Public

There is much wringing of hands about the problem of "scientific illiteracy." Every year scientistis, educators, and government officials sound ever more urgent alarms about the impact of this on our country's future. A recent study, for example, estimated that only 6 percent of American adults meet "a minimal definition of scientific literacy to function effectively in citizenship and consumer roles." (Piller, 1991: 32) Whenever safety or health concerns erupt over specific technologies, many lament about the difficulty of getting the public to look rationally at risks and its inability to "balance fear against the reality of statistics." (Passell, 1989: A1) Spokespersons for science and industry continually complain about the latest "scare of the week." We hear a lot about "junk science" in the courtroom (Huber, 1991), the rise of Nimbyism, i.e., the "not-in-my-backyard" syndrome, and the irrational demand for a "fail-safe society." (Piller, 1991)

Yet, too often over the past fifty years the general approach of both private and public institutions in dealing with the public on scientific and technological matters has been to apply the mushroom theory of management, i. e , keep them in the dark and, if problems should surface, feed them manure. The cummulative result "casts a shadow over the public's trust not only in controversial products such as silicone breast implants, but also in the entire corporate, regulatory and medical system that sanctioned their use." (Editorial, 1992: 14)

The Silicone Breast Implant Controversy

The health questions surrounding the implantation of silicone breast implants fall under this pattern. Despite being implanted in approximately two million women during the past thirty years, remarkably little is known with certainty about them and their safety. As a result, some critics have charged that women have been used as guinea pigs in some vast experiment. But the evidence suggests that "experiment" is too scientific a word for the poorly researched and weakly regulated implants. (Goodman, 1992: 15) Although there has only been a public uproar over silicone breast implants during the last two years, disagreement over their safety has simmered since the 1960's when scientists introduced them to replace injections of liquid silicone, which in some cases led to disfigurement and sores that would not heal. As one plastic surgeon at Lahey Clinic in Boston has stated, "This controversy is not new. It's been brewing for many years." (Becker, 1992: 5) Complications associated with

silicone implants range from localized, painful, and in some cases, disfiguring conditions like capsular contracture and inflammation to systemic autoimmune symptoms and diseases, such as scleroderma, rheumatoid arthritis, lupus erythematosus, Raynaud's phenomenon, and Sjogren's Syndrome.

Amazingly enough, by the time the Food and Drug Administration (FDA) asked for a moratorium on the implantation of silicone breast implants on January 6, 1992 and then ruled on April 16, 1992 that they would be available only through controlled clinical studies, the central questions surrounding them and their safety remained unanswered. These included the frequency and severity of associated health problems, the connection, if any, between the implants and immune-related diseases, how long the implants last or what percentage will rupture, the chemical composition of the gel, the applicable performance and manufacturing standards. (Kessler, 1992: 1713)

The information that has dribbled out over the past several years under the pressure of litigation and regulatory hearings now indicate that Dow Corning, the leading manufacturer of silicone breast implants, misled regulators, physicians, and consumers about the extent of uncertainty within the company itself about the safety of these implants. Although safety questions were raised repeatedly over the years, as Dow Corning produced new models of the implants, no thorough scientific studies were carried out to answer these questions.

As in other controversies involving medical devices, the operating principle of Dow Corning's manufacturing process seemed to be "Earn as you learn." (U. S. Congress. House. 1990) For example, the company knew in the 1970's that the devices might leak or rupture and that silicone might provoke some kind of immune response. In studies begun in the 1970's Dr. John Paul Heggers of the University of Texas medical campus at Galveston showed that the human immune system reacted to the silicone in breast implants by making antibodies against it. The antibodies attack the silicone and the body's own tissues associated with it. For more than a decade he had tried to persuade Dow Corning to carry out such research but was rebuffed. (Hilts, 1992b: 1)

Yet, in rushing a new model on the market before the 1976 regulation governing medical devices took effect, Dow Corning began producing and marketing the implant even before the results of preliminary studies were in and before technicians had resolved a key technical question: Will the newly formulated gel "bleed" or leak at an

excessive rate? Instead of answering the question, a memo was sent out to salespersons, instructing them how to scrub the implants before showing them to plastic surgeons. In 1976 Dow Corning received a series of complaints from doctors who saw severe inflammatory reactions in women after the implants had been in place for a short time, as well as silicone migrating in women's bodies. In a June 1976 memo, one Dow official wrote, "I have proposed again and again that we must begin an in-depth study of our gel-envelope, and bleed phenomenon. Capsular contracture isn't the only problem. Time is going to run out for us if we don't get under way." (Hilts, 1992a: B10) He warned that plastic surgeons were becoming disturbed and might begin studies of their own.

In one 1977 memo, a marketing executive admitted misleading plastic surgeons when he told them certain safety studies were under way. In 1983, Dow scientist Bill Boley wrote, "I want to emphasize that, to my knowledge, we have no valid long-term implant data to substantiate the safety of gel for long-term implant use." (Foreman, 1992: 29) Also in 1983, a quality control manager wrote in response to complaints about ruptured implants, "To our embarassment, we were unable to provide more than tissue culture and heavy metals analysis. Furthermore, our product literature on these gels imply that safety testing to qualify them as implant materials does exist." (Ingersoll, 1992b: A8)

In 1987 Dow became aware that employees for several years falsified certain documents concerning the manufacture of its implants "in violation of company policy and procedures." The records in question deal with the temperatures at which liquid silicone was heated or "vulcanized," before being placed in the implants. That heating process is what turns liquid silicone into a thicker gel with less tendency to ooze from the implant throughout the body. It is this migration--called gel bleed-that is at the center of the main dispute over implants. Dow never made its findings public nor alerted the FDA until this past November. Because of the falsified records, Dow admitted it had supplied the FDA with incomplete and thus inaccurate data earlier last year. (Burton, 1992: A3)

Continuing disclosure of such information should raise questions of credibility even in the minds of those who have vigorously defended the safety of silicone implants. Instead, it allows them to adopt a "moving target" strategy of defense. Dr. Norman Cole, the president of the American Society for Plastic and Reconstructive Surgeons (ASPRS) exemplified this strategy in his attack on the FDA's moratorium on the implantation of silicone breast implants: "The FDA should differentiate between scientific data on the modern-day implants and data on a specific

manufacturer's obsolete implants or business operations." (Ingersoll, 1992a: B5)

However, it seems more appropriate that physicians' concerns about the FDA's actions pertaining to implants should focus on why it took so long for the FDA to require more rigorous studies on the safety and efficacy of silicone breast implants. The FDA has been empowered to regulate medical devices, including breast implants since 1976 when Congress passed device amendments to the Food, Drug, and Cosmetic Act. Because there were over 100,000 devices already on the market, existing devices were permitted to be sold until the FDA could call for and review their safety data. In 1982 the FDA announced that breast implants would be placed in the category for devices requiring proof of safety and efficacy, indicating there was insufficient evidence to provide reasonable assurance of their safety and efficacy. It took another six years, during which time approximately half a million women received implants, for the FDA to initiate the review process with a call in June 1988 for premarket approval applications (PMA) in the Federal Register. This started the clock on a legislatively prescribed series of deadlines giving the manufacturers thirty months to submit their PMAs. (Fisher & Brody, 1992)

According to investigations by the Human Resources and Inter-Governmental Relations Subcommittee, headed by the late Rep. Ted Weiss, the concerns of FDA scientists about breast implants were blocked by higher-level agency officials for fifteen years. While FDA officials argue the agency had more pressing regulatory priorities to deal with, such as heart valves and AIDS drugs, Rep. Weiss's summation of the FDA's delayed action on breast implants was that "Unfortunately, the ruling philosophy has been 'Let the buyer beware!'" (Regush, 1992: 29)

The FDA and Women's Right to Choose

One of the most surprising responses to the decision by Dr. Kessler, the commissioner of the FDA, to remove silicone breast implants from the open market was an editorial in The New England Journal of Medicine, written by Dr. Marcia Angell. One would expect the editors of The Wall Street Journal to go ballistic over the efforts of the FDA to determine the safety of breast implants, because as a Wall Street Journal editorial stated during the height of the public controversy over breast implants, "Dow Corning's primary responsibility is not to defend the truth, but to produce returns for shareholders." (Editorial, 1992: A 12) But the editorial response of Dr. Angell, entitled "Breast Implants--Protection or Paternalism?", was puzzling in many ways.

She objects to the decision as patronizing women and defends the right of women to make their own decisions. There is no doubt that she addresses an important and sensitive issue. However, one has to ask whether at that point in the breast implant debate, the choice issue had not already been sufficiently co-opted by The Wall Street Journal, with its editorial attacks on the FDA's intrusion into the free market of breast implants, and the ASPRS, which throughout the entire debate operated more like a commercial enterprise than a collegial medical society. (Rigdon, 1992: A1) As one commentator wrote, "It never fails to astonish: The very people who gleefully mislead and harm women for profit will, when put for once on the defensive, lay claim to the rhetoric of 'women's choice'." (Wolf, 1992: A17) It is difficult to understand why Dr. Angell would even raise the issue of choice for women because, in the face of the kind of scientific uncertainty, ignorance, and corporate deception that surrounds silicone breast implants, informed consent is an empty concept. As Arthur Caplan, director of the University of Minnesota Center for Biomedical Ethics, has stated, "If you do not have data on the range of risks and problems, you are not free to choose, you are free to be ignorant. Informed consent requires both information and choice. Since the companies have not supplied the information, this is a dubious choice." (Foreman, 1992: 25)

Dr Angell states that "the issue is the balance between risks and benefits" and then acknowledges that "Kessler argues persuasively that the risks have not been adequately defined...." She also admits "there is clearly a disparity between the little that has been demonstrated about the risks and the abundance of anecdotes now being related in the media and the courts." (Angell, 1992: 1695) Then why argue for the right to weigh risks and benefits against the background of so little verifiable evidence one way or the other, especially considering that those promoting the use of implants had thirty years to gather such evidence? In addition to the lack of adequate information to make an informed choice, there is the problem of deliberate misinformation. Even under intense public scrutiny Dow Corning continued to give misinformation to women on the hotline they established as part of their crisis management strategy! (Ingersoll, 1991: B1) Moreover, a sample of plastic surgeons by a Wall Street Journal reporter revealed that these doctors continued to stress size not risks to their prospective patients. (Berentson, 1992: A4)

Dr. Angell also argues that "people are regularly permitted to take risks that are probably much greater than the likely risk from breast implants; they do so when they smoke cigarettes, for example, or drink

alcohol to excess." (Angell, 1992: 1696) Is this a physician writing? If anyone should be sensitive to the difficult problems of choice involving addictive substances and behavior, it should be the editor of a medical journal that carries so many articles on the subject. Dr. Angell's comparative evaluation of dissimilar risks is a common diversionary tactic by proponents of a given technology when questions of risk are raised about that technology.

Dr. Angell argues that the FDA decision "has the effect of coercing women with breast cancer to become subjects of clinical studies....Yet, according to federal regulations for the protection of human subjects, participation in clinical studies must be entirely voluntary." (Angell, 1992: 1695). But only one in ten women who undergo a mastectomy have reconstructive surgery, and for those who do, there are other options available besides silicone implants.

One also has to ask whether the choice issue has not been superceded by other concerns, especially from a medical perspective. For example, it seems the tracking of patients with medical devices like breast implants would be a more pressing concern. Our supermarkets have better scanning equipment and database tracking software than our hospitals and their supply companies. If Sears and Walmart can track customers cheaply, it would not seem unreasonable to expect companies making medical devices to also be able to do so. (Schrage, 1992: 78)

Dr. Angell next raises a theme that appears in practically every health and safety controversy involving science and technology: the specter of fear. If corporate executives, scientists, and technical people were as sensitive to the health and well-being of the public and consumers as they seem to be about frightening them with information, they would not have to be so worried about creating fear and panic among the masses. Dr. Angell states that "the FDA decision has given rise to great fears among the 1 million women now living with implants--fears that in many women are out of all possible proportion to what is known about the risks." (Angell, 1992: 1695) Has there *ever* been a case where the defenders of a particular technology didn't believe this, especially when women are involved? When the FDA asked for a moratorium on silicone breast implants in January 1992, an official of the American Medical Association said, "There will be absolute hysteria among women." (Barringer, 1992: B9) Dr. Norman Cole, president of the ASPRS said the FDA moratorium had "created hysteria, anxiety and panic" among women. (Barringer, 1992: B9) Since Dr. Angell later raises the issue of sexism in her editorial, it is

peculiar that she does not call attention to the fact that this kind of language is never used in reference to men.

Dr. Angell believes the FDA decision ignores the social context in that "targeting a device used only by women raises the specter of sexism--either in having permitted the use of implants in the first place or in withdrawing them." (Angell, 1992: 1696) Of course it does, especially since the FDA permitted their continued use without requiring proof of their safety and efficacy. As a female physician, Dr. Angell must be aware of many similar instances of sexism throughout the practice of medicine. Would she make the same argument in defense of the Dalkon Shield or Proctor and Gamble's Rely Tampon? A more fundamental question pertaining to social context and sexism involves body image stereotypes and why women feel compelled to have their breasts changed in the first place. The key problem regarding the social context of breast implants is not the issue of paternalism, but rather that society makes impossible demands on women to look a certain way. Psychologist Rita Freedman, who has written two books on beauty and body image, states, "Women have a difficult time living in their bodies in this social system. Therefore, we are motivated to transform (ourselves) at great cost because we feel the cost of not transforming is even greater." (Foreman, 1992: 29) The ultimate question that Dr. Angell should be raising is whether cosmetic surgery, a medical solution, is an appropriate response to the socially constructed problem of poor body image.

Conclusion

Scientists, engineers, physicians, manufacturers, and government regulators--everyone involved in the development and application of technology--cannot be held accountable for everything that goes wrong. But it is absolutely essential that they assume responsibility for telling everything. Organizations like the National Association of Science, Technology and Society must seriously address the social, political, and economic obstacles to the fulfillment of this responsibility. Until this is accomplished, the lofty goals of scientific literacy and "empowering citizens to question, understand and guide" science and technology will remain empty rhetoric.

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BIOETHICS EVENT-BASED FUTURE WORKSHEET

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Current critical events in the news can best be understood if seen as a product of the past, and as influencing factors in the future. Simplistic responses may be catastrophically counter-productive. Ray Bradbury has said that he writes science fiction not to predict the future but to prevent it. Making decisions involves forecasting possible alternative futures, and deciding upon a course of action most likely to achieve one of the better-case scenarios. This implicitly assumes a value system, but unless those values are made explicit one is more likely to make decisions regretted later. Eric Severeid said, "The greatest intellectual discovery of the Twentieth Century is that the Cause of Problems is Solutions." The following framework incorporates many futurist techniques in responding to a current issue of Science/Technology/Society presented in a newspaper, magazine, TV, radio, motion picture, song, or rap example brought to the class by the teacher or students.

OBJECTIVES: The student will be able to demonstrate ability to:

1. Identify a decision that society must make based on a current event involving environmental or technological issues.
2. Identify how issues become controversial due to conflicts among values involved.
3. Explain how past events and trends have influenced a current event.
4. Show how investigating current trends and likely discoveries help forecast the future.
5. Use the Delphi technique to forecast dates of future events.
6. Use a Cross-Impact Matrix to show interaction of factors in changing the future.
7. Create visions of alternative futures and identify values that would likely be enhanced or threatened in their development.
8. Identify societal actions to make alternative futures more or less likely.
9. Construct a scenario in a choice of media demonstrating what such a future world might be like.
10. Examine the controversial decision in the light of its likely outcomes and of the values involved and propose an ethical decision.
11. Identify personal actions the student can take now to help bring about a desirable future.

TIME FRAME: One or two of these components could be chosen for a discussion of 15 minutes, while the entire framework could be used for a week or more. It can also be used as an evaluation test on a new issue by students familiar with the procedure in a single class period.

AGES: High School to Adult.

PROCEDURAL NOTES TO THE TEACHER:

The event can be brainstormed by the class. The teacher or students can bring in clippings from the newspaper or magazines, or news or documentary TV or radio tapes about current issues related to applications of scientific knowledge to individual, group, or governmental decisions.

The entire class can be involved in **WHOLE-CLASS TEACHER-LED DISCUSSION,** with each part explained by the teacher, and contributions open to all class members, based on prior knowledge. The worksheet could then be a catalog of approaches to consider. The number of lines on each section of the worksheet is not meant to limit the number of contributions from the class. Several strategies could arise from the discussion:

SMALL COOPERATIVE LEARNING groups could take either the same issue or a different one and use outside resources in the school or community library, or letters or interviews with experts, to gather more information.

EACH SMALL COOPERATIVE LEARNING group can also take a different issue and divide up the different parts such as trends, discoveries, desirable and undesirable futures, the matrix, etc. They then report back to the total class so that a number of topics can be researched simultaneously.

The **DELPHI** should be done by more than one student. Each student can make one event prediction, or predictions can be brainstormed and voted upon. It is important to note that these are datable events, not continuation of trends. The dates are individually chosen by students (outside people can also be asked, including experts in the fields). "Already" and "never" are also options. Dates are then tallied, and the 25th-75th percentile range is considered the most likely time span for a reasonable forecast. This is the short-form approach. However, many futurists would say only the three-cycle approach deserves to be called DELPHI. In this longer form, commonly mailed or faxed to other participants, the SECOND ROUND lists the 25-50-27 %ile dates. Each person is asked to examine those and again choose a most likely first occurrence. If participants' dates are outside the 25/75 range (inter-quartile), they also write their reason for believing it will occur earlier or later. These are again tallied. In the THIRD ROUND participants are given the second round's 25/50/75%iles, and also the arguments given for earlier or later dates. If a date within the inter-quartile is chosen in this third round, the participant must answer the second round arguments for choosing an earlier or later date. The final dates come from this third round where each participant has been challenged to justify a date.

CROSS-IMPACT MATRIX. From among trends, new technologies, and Delphi events, participants select those felt to have major impact on the siuation chosen, placing these in the left column and in the same order across the top. Using ++, +, 0, -, and -- symbols, in each box individuals indicate the result they believe the factor in the left column would have on the factor in the top column. This helps identify how these are interdependent and do not occur in a societal vacuum. It also identifies those points more susceptible to influence, as well as those that may be involved in feedback loops.

VALUES. While the forecasts themselves can be made without examining values, the choice of what society or the individual should do to make a **desired future** more likely necessarily involves value choices. The class can brainstorm the kinds of values that underlie gaining knowledge, economic equity, leisure time, freedom of opportunity, consumer goods, preservation of ecosystems, sustainable development, animal rights, etc. Students can choose from the "Values for BioEthical Decision" list or propose their own. By ranking values, they can as a class or as individuals decide on the best option(s) to try to affect that future, especially after devising and sharing dramatic scenarios of what such futures might be like.

SCENARIOS. Any approach such as an account from a future history text, a script for a TV documentary, an eye-witness report of watching a future demonstration or riot, a text of a bill to be passed by Congress or the United Nations, a cartoon, a political campaign speech, a legal argument in court, or a dramatic skit can be used. The demonstration of future scenarios can be done individually based on a single description of such a future seen from different perspectives. Alternatively, a group can perform a dramatic enactment of life in such a future.

WHAT INDIVIDUALS CAN DO. The class can discuss the pros and cons of various responses such as joining citizens' action and lobbying organizations, preparing presentations to take to other classes, speaking at school board or city council meetings, public demonstrations, writing letters to the newspaper or to elected officials, changing the way they live their own lives with regard to purchases, driving, recycling, etc. The class can then organize to have all or selected members of the class carry out the activities they decide will be most influential.

VALUES FOR BIOETHICAL DECISIONS
(adapted from Jon Hendrix, Ball State University)

ACHIEVEMENT--accomplishment brought about by hard work to attain desired outcome or goal.

ALTRUISM--concern for the interests of others.

ANIMAL RIGHTS--other species should not have to endure pain and suffering for human ends.

AUTONOMY--self-directed, capable of existing alone, acting without aid of others, responsible for self.

BEAUTY--quality of integrated balance and proportion causing feelings of appreciation, awe, exultation.

BEING LIKED--being held in favor or regard by others.

CONSERVATISM--preserving best of past, maintaining current conditions, avoiding abrupt changes.

COOPERATION--working together for mutual benefit.

CREATIVITY--initiating new and innovative ideas and designs.

DEMOCRACY--decisions made by group, or elected representatives, rather than elite rulers.

DIVERSITY--variety of cultures, viewpoints, lifestyles, values, species living together.

EDUCATION--gaining knowledge & skills while developing reason, judgment, intellectual maturity.

EMPATHY--ability to share in someone else's feelings.

EMOTIONAL WELL-BEING--freedom from overwhelming anxieties, piece of mind, inner security.

EQUALITY --being equal or treated equally with regard to quality, degree, value, rank, or ability.

FAMILY / BELONGING--being united by certain convictions, characteristics, marriage, or social unit.

FRIENDSHIP--state of one person being attached to another by feelings of affection or personal regard.

GREATEST GOOD FOR GREATEST NUMBER--try to achieve utilitarian balance as much as possible.

HEALTH--soundness of one's body, freedom from disease or pain.

HONESTY--fairness or straightforwardness of conduct, integrity, not deceiving or stealing.

HUMAN DIGNITY--a high esteem for all humans regardless of age, race, or creed.

INTERDEPENDENCE--the mutual need for support, aid, comfort; positive interactions benefit all.
INTIMACY--a close, familiar, and usually affectionate or loving personal relationship.
JUSTICE--quality of being impartial to treat others fairly or adequately.
KNOWLEDGE--seeking truth, information, or principles for satisfaction of curiosity, for use, or for the power of knowing.
LIBERALISM--open-minded, welcoming new knowledge and choices, protecting rights of others.
LOVE--affection based on admiration or benevolence, unselfish devotion, great appreciation.
LOYALTY--allegiance to a person, group, institution, or political entity.
MAINTAIN OPTIONS--don't prevent future choices by actions taken today.
MORALITY--moral values held by an individual or society.
NONMALEFICENCE--do no harm by one's action; don't make matters worse.
OPPORTUNITY--possibility of making variety of different decisions, chance to pursue other values.
OWNERSHIP--having material objects, or acknowledging specific ideas as being part of your ideology.
PHYSICAL APPEARANCE--concern for the beauty of one's own body.
PLEASURE--an agreeable emotion accompanying the possession or expectation of what is good or greatly desired, a state of gratification.
RIGHTS--those things one is due because of citizenship, moral standing, or membership in a class.
DUTY TO POSTERITY--preserve world in good shape for those to come after; safeguard their inheritance.
PRESTIGE--holding a position of high value relative to society's standards.
POWER--possession of control, authority, or influence over others.
RECOGNITION--being made to feel significant and important, given special notice or attention.
RELIGIOUS BELIEFS--one's convictions or opinions about religion, faith, devotion, ultimate values.
RESPONSIBILITY--legally or morally accountable for results of actions, choosing right from wrong, taking care for rights of others.
SELF-CONTROL--restraint of oneself or one's actions, feelings, or passions.
SELF-PRESERVATION--looking out for your own welfare.
SELF-WORTH--a feeling of being useful and/or held in high esteem by others.
SKILL--ability to use one's knowledge effectively and readily in execution or performance, expertise.

SOLITUDE--state of being removed from society, a quiet life.
SUSTAINABILITY--being able to continue functioning or using resources at this level indefinitely.
TOLERANCE--allowing or having sympathy for conditions, beliefs or practices different from your own.
TRUTH--conforming to a universal or generalized reality, fact.
WEALTH--abundance or valuable material possession or resources, affluence.
WISDOM--ability to discern inner qualities and relationships, insights, good sense, judgment.
WORK / LABOR--exertion or effort directed to produce a product or accomplishment, toil, effort.

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BIOETHICS EVENT-BASED FUTURE WORKSHEET

Richard G. Dawson, Shawnee Mission South H.S.,Overland Park, KS 66207

HEADLINE FOR CURRENT EVENT____

DECISION PROBLEM: What controversial decision must be made about this issue? List at least two options:____
____
____

ETHICAL VALUES PROBLEM; List 2 or more important values that will be in conflict in making this decision____
____

KEY PAST EVENTS INFLUENCING CURRENT EVENT:

Past Event	Values Enhanced	Values threatened

TRENDS RELATING TO CURRENT SITUATION OVER PAST 25 YEARS

INCREASING:____
____
____

DECREASING:____
____
____

UNCHANGED OR
FLUCTUATING____
____

TRENDS LIKELY OVER NEXT 25 YEARS RELATING TO CURRENT SITUATION:

INCREASING:____
____
____

DECREASING:____
____
____

UNCHANGED OR
FLUCTUATING____
____

NEW DISCOVERIES OR TECHNOLOGIES THAT ARE LIKELY TO AFFECT THIS FUTURE:

Discovery/Technology	Expected Effect

DELPHI FORECAST: FUTURE EVENTS LIKELY TO HAVE IMPORTANT EFFECT ON THIS ISSUE	YEAR WHEN EACH WILL FIRST OCCUR

CROSS-IMPACT MATRIX. Place significant factors identified down left side and same at top right. Place PLUS if left factor will make top/right more likely, MINUS if less likely:	TRENDS			TECHNOLOGIES			EVENTS		
TRENDS									
TECHNOLOGIES									
EVENTS									

DESIRABLE FUTURES: What future situations or outcomes do you think would be best ?

	VALUES THAT WOULD BE ENHANCED	VALUES THREATENED

WHAT ACTIONS BY SOCIETY WOULD MAKE THESE DESIRABLE FUTURES MORE LIKELY?

UNDESIRABLE FUTURES: What future outcomes do you think would be worse?

	VALUES THAT WOULD BE ENHANCED	VALUES THREATENED

WHAT ACTIONS BY SOCIETY WOULD MAKE THESE UNDESIRABLE FUTURES LESS LIKELY?

BETTER-CASE SCENARIO: SHOW A PIECE OF WHAT YOUR OWN FUTURE MIGHT BE LIKE IF THE "DESIRABLES" ABOVE REALLY HAPPENED. You can write a short story, news report, poem, drawing, cartoon, etc.

WORSE-CASE SCENARIO: SHOW A PIECE OF WHAT THAT FUTURE MIGHT BE LIKE IF THE "UNDESIRABLE" EVENTS OR ACTIONS OCCURRED

ETHICAL VALUES: LOOK BACK AT YOUR DECISION PROBLEM & ETHICAL VALUES. WHICH VALUES ARE MOST IMPORTANT IN CHOOSING YOUR BEST OPTION?

ETHICAL DECISION; BASED ON THESE VALUES, WHAT DECISION SHOULD BE MADE ABOUT THE PROBLEM?

PERSONAL RESPONSIBILITY: WHAT CAN YOU DO RIGHT NOW (NEXT FEW MONTHS) TO HELP BRING ABOUT THE DECISION THAT SUPPORTS THE VALUES YOU RATE HIGHEST?

SUSTAINABLE DEVELOPMENT: SOME INTERPRETATIONS, IMPLICATIONS, AND USES.

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With the embrace of the concept of 'sustainable development' at the recent United Nations Conference on Environment and Development (UNCED), a new consensus appears to be emerging in Development thinking. Development is rehabilitated as a commendable objective and a desirable process if a few of its accompanying problems, mainly environmental and social, are resolved by the application of a progressive, forward-looking principle like sustainability. This simple equation — sustainable development = sustainability + development — is being promoted by experts and policy-makers despite persistent failures of conventional development efforts and despite the availability of a vast literature documenting the ambiguities, complexities, shortcomings and gross mistakes of *every* development strategy tried in the second half of this century.

This paper attempts to go beyond the fashionable interpretation of sustainable development and present, instead, an emerging Third World perspective on development and its relevance to the poor and their needs. The paper seeks first to characterize the Western idea of development and to describe briefly the dominant development strategy based on the Western ideology. Then the evolution of the concept of sustainable development is traced as an outgrowth of mainstream efforts to integrate social and environmental concerns within the prevailing idea of development. With the appearance of *Our Common Future,* the report of the World Commission on Environment and Development (WCED), sustainable development is argued to have achieved political and scientific respectability, paving the way for its elevation to official doctrine at UNCED. The fourth section describes two interpretations reflecting the anxieties and priorities of the Third World on development strategy. Comparing these with the WCED framework is the subject of the fifth section. A critique of the WCED is presented in this section, based on the idea of "sustainable livelihood" (Chambers 1986). In the last section, the problem with the WCED framework is illustrated using a controversial dam project in India.

WESTERN MODELS OF DEVELOPMENT

Most of the discussion on development, though not always stated explicitly, is invariably directed at what are called underdeveloped, less developed, or developing countries. For these countries, after winning their independence from their colonial masters in the twentieth century, development was supposed to be the way to achieve equal economic and political status. Taking cues from the industrial success of the West, these countries were enamored to imitate the western models of development as pathways to prosperous futures. Wolfagang Sachs illustrates

this ideological foundation of development strategy by quoting U.S. President Truman, who described development as an effort "[to] relieve the sufferings of these [poor] peoples" through "industrial activities" and to give them "higher standards of living" (Sachs, 1990: 42).

The academic community in the West largely agreed with Truman, regarding the Western model of economic, social, and political organization as the best means to develop Africa, Asia and Latin America. Indeed, in the minds of many, the question was not whether, but how quickly the Western model should spread. Anything less than full mobilization of the West's resources and technology in this effort was considered to be unethical. Redclift describes a key assumption of the rush to Westernize the world, using the words of Humphrey and Buttel: "their collective celebration of Western social institutions [has caused them to regard] energy-intensive industrial development as the natural end point of a universal process of social evolution and modernization" (Redclift, 1988: 636). Thus, westernization was taken to transcend not only economic but also social, cultural, and political differences among nations. All walks of individual and social life were expected to be brought into the process of development.

The power of the Western ideology was not limited to Westerners only. Despite being part of the Gandhian tradition of anti-materialism, Nehru, for example, vigorously supported putting India on the path of westernization. His proclamation that large dams and steel plants were "new temples of India" indicates not only an enthusiastic embrace of Western values and institutions but also a concomitant abdication and defiling of indigenous ones (Parthsarathi, 1990: 1694).

The essence of the Western model of development has been the replication of Western values, institutions, policies, and organizations in the integration of the Third World into the world system. Economic growth (in terms of increased GNP) has served as the central idea and prime-mover of development in this model. The focus on economic growth has remained even though, after four decades of its pursuit, the results for the Third World are far from the promise of economic and political parity. As Robert MacNamara, the President of the World Bank, admitted in 1978, despite the unprecedented increase in GNP of many of these countries, "800 million people continue to be trapped in ... absolute poverty" (Chambers, 1983: 1).

The Western development strategy has failed to produce clear evidence that it can improve the material, social, or political conditions of the Third World in a manner that addresses the needs of its people. Yet, this idea of development and the centrality of economic growth have not been abandoned. Instead, the Western model has been recently supplemented with adjunct objectives and with refinements of methods in order to respond to the dual pressures of environmental degradation on a global scale and the increasingly poor performance of economies of developing countries.

EVOLUTION OF THE CONCEPT OF SUSTAINABLE DEVELOPMENT

The idea of sustainable development can be traced back to the Cocoyoc Declaration in 1974. The concept was mainly used to call attention to the ecological limits to natural resource depletion and economic growth (Redclift, 1987: 32). The concept gained prominence after publication of the World Conservation Strategy (WCS) in 1980. The WCS provided a three

pronged definition of sustainable development: (a) maintenance of ecological processes and life support systems; (b) utilization of natural resources at rates which allow replenishment; and (c) maintenance of genetic diversity (Redclift, 1987: 20). As Redclift has observed the World Conservation Strategy provided an "environmental rationale through which claims of development to improve the quality of (all) life can be challenged and tested." (Redclift, 1987: 33).

A similar concept — co-evolutionary development — was offered in the 1980s to better draw out linkages between economic and ecological paradigms of development (Norgaard, 1984). Critical of economists for their short-sighted and mechanistic views, this approach encouraged an organic understanding of the relationship between society and nature.

A somewhat more comprehensive term — eco-development — sought to link not only the economic and ecological perspectives of development, but also to encompass the social and political content of sustainability (Redclift, 1987: 34). The term was used to mean many things. In one interpretation, eco-development was restricted to mean regional resource planning guided by technological considerations. Others such as Ignacy Sachs used the term to call for radical changes in international economic and political structures and moral commitments (Sachs, 1984). An intermediate conception of eco-development called for a triangular model relating basic human needs, community self-reliance, and ecological sustainability. Many viewed the interplay of political and ecological interests as the key factor in the concept of eco-development.

Redclift describes a fourth position which he traces to the work of Robert Chambers. Chambers objects to the paternalistic attitude implicit both in environmental and development thinking which tend to prescribe to poor countries what is good for them. He contends that for the poor, livelihood and security are more important than ecological sustainability and hence these concerns should be given due priority. His position is that only by securing short term and immediate support for livelihood, can we ensure uses of the environment which are truly sustainable for human beings as well as for the biosphere. Thus, what Chambers calls 'sustainable livelihood thinking' seeks to establish causal relationships between development and livelihood and between environment and livelihood in order to realize a socially grounded concept of sustainability (Redclift, 1987: 36).

THE WCED SCHOOL OF DEVELOPMENT

In historical review of the sustainable development literature, Lele depicts various semantic interpretations and conceptual approaches to sustainable development (Lele, 1991). He explains how sustainability is interpreted alternately as ecological sustainability affected only by "bio-physical" conditions or as social sustainability focussed on social conditions. According to Lele "social sustainability" can be defined as "sustainability of infrastructure, government, and services", as " sustainability of political and social institutions", or as "cultural sustainability in terms of values and belief systems" (Lele, 1991:615). He points out that, in both the ecological and social aspects, the equation of sustainable development with [development + sustainability] represents the mainstream interpretation dominating the debate. In essence, he argues that sustainability and development have been combined to mean "sustained growth", "sustained

change", or as "successful development". This mainstream viewpoint is epitomized in *Our Common Future*.

CONTRIBUTION OF THE WCED REPORT

The WCED report synthesized nearly fifteen years of thinking on sustainability issues surrounding development. The Commission relied on worldwide hearings, national government representations and other techniques of consensus building to produce a conceptual framework acceptable to a range of interests and sections of the world. Upon its release, the report received wide acclaim and criticism and inspired convening of the United Nations Conference on Environment and Development (UNCED) at Rio de Janeiro in June 1992. Thus, a major contribution of the WCED Report was to elevate the concept of sustainable development to the status of an international concern and focus. In preparation of UNCED, the United Nations (UN) General Assembly directed all UN agencies "(to) review their policies, programs, budgets, and activities aimed at contributing to sustainable development " (FAO, 1990: 1). The WCED report had recommended precisely this action in its call for national and international reforms.

SUSTAINABLE DEVELOPMENT IN THE WCED REPORT

In this section, the WCED conceptual framework is presented organized in three steps — the definition of sustainable development used in the report, the key concepts underlaying the report's idea of sustainability, and the critical objectives identified.

The WCED report defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987: 43). This definition focuses on two dimensions — a resource or environmental dimension and a socio-economic or development dimension. The report tries to capture two important issues in these dimensions through the two key concepts it presents. As to the socio-economic dimension, the report advocates "overriding priority to the ... essential needs of the world's poor". In resource dimension, the report reiterates "limitations ... on the environment's ability to meet present and future needs" (WCED, 1987: 43).

In essence, the report argues that the development problem can be resolved by providing the poor with their "essential needs", and that the environmental problem fundamentally is one of observing natural limits in the conduct of social activities. In promoting an agenda of basic needs and development sensitive to natural carrying capacities, the WCED sought to bring practical resolution to the interlocking crises of poverty and environmental degradation. This practical orientation of the commission is evidenced by the seven "critical objectives" set out in the report for future action (WCED, 1989: 49):

(1) reviving growth in the Third World,
(2) changing the quality of growth to include environmental protection,
(3) meeting essential needs for jobs, food, energy, water, and sanitation,
(4) ensuring a sustainable level of population,
(5) conserving and enhancing the natural resource base,
(6) reorienting technology and managerial risk to reduce environmental and social threats,
(7) merging environment and economics in decision making.

Lele calls these 'operational objectives' and argues that their logical connection is basically with ensuring ecological sustainability for future generations (Lele, 1991: 611). In this respect Lele points out that the mainstream concept of sustainable development is essentially managerial in nature.

THE REDCLIFT CRITIQUE

Michael Redclift makes a three-pronged critique of the Commission's concept of sustainable development. He challenges the mainstream approach as "ethnocentric and ahistoric" (Redclift, 1988: 648). According to him, historical analysis is essential in understanding the sources and implications of equating development with economic growth. Through such an analysis, it is possible to expose the social and environmental exploitation accompanying capitalist model of development.

While accepting the need to give priority to the livelihood of the poor in sustainable development, as suggested by Chambers, and while accepting the prospect of imminent breakdown of the ecological system if economic growth is continued, Redclift suggests that there is a third precondition for sustainable development. He contends that the political impediments in achieving sustainable development are equally important and that understanding the interconnected local, national, and global networks of political and economic interests is essential to fashioning a sustainable development strategy. Redclift asserts that:

> "sustainable development... means more than seeking a compromise between the natural environment and the pursuit of economic growth. It means definition of development which recognizes that the limits of system have structural as well as natural origins" (Redclift 1987: 199).

His inclusion of political factors in the analysis of development springs from his emphasis on political economy of ecological compulsions.

A THIRD WORLD PERSPECTIVE ON SUSTAINABILITY

Alternate development thinking which is focussed on the problems and priorities of the Third World, is generally dissatisfied with the positions of the WCED, including its narrow definition of development as economic growth, its belief that poverty and population growth are the main obstacles in halting environmental destruction, and its remedy of economic growth for the problems of poverty and environmental degradation. Recently southern and northern non-governmental organizations (NGOs) came together to offer alternative analyses and conceptual frameworks with different emphases on the problems of environment and development. Their efforts were aimed at recovering the concept of sustainability and to address the actual Third World conditions and needs. A second effort linking energy issues to those of environment and development similarly revises sustainability to address Third World conditions and aspirations. Both frameworks are summarized below.

It is important to note that, the Third World perspective represents diverging interests and ideologies and hence there should be an element of caution observed in grouping them together.

AN NGO PERSPECTIVE: SIX PRINCIPLES OF SUSTAINABLE DEVELOPMENT

In a book *Beyond The Brundtland*, a coalition of southern and northern NGOs came to agreement on six principles of sustainable development (Court, 1990: 136). This framework is atypical in its comprehensive scope but quite representative in its priorities and directions. These six principles, though general in character, are claimed to be basic and addressing fundamental issues. They are meant to emphasize the strong interrelatedness of social and environmental considerations and to avoid exclusive attention to environmental issues that are in good currency at present.

The six principles are as follows.

(a) The principle of cultural and social integrity of development: This requires that development grow from within, and not to be imported from the outside.

(b) The ecological principle : This insists upon sustainable forms of resource utilization.

(c) The solidarity principle : This calls for equitable access, distribution, and exchange among all people.

(d) The emancipation principle : This entails empowerment and participation of the underprivileged and marginalized sections of the society.

(e) The non-violence principle : This seeks development in a peaceful manner in a direct as well as in a structural and institutional sense.

(f) The principle of error-friendliness : This is intended to allow for mistakes without endangering the integrity of the eco-systems and resources base.

THE SOCIAL GOALS OF GOLDEMBERG ET AL.

Energy for a Sustainable World, the famous collaborative effort by four respected energy researchers, offers an agenda to meet the Third World's social and environmental objectives based on a rigorous techno-economic analysis. Although the subject matter of their work is mainly energy, the authors vividly describe the concept of sustainability: the goal of a sustainable world, must embody these social goals — equity, economic efficiency, environmental soundness, long-term viability, self-reliance and peace.

A brief explanation of these goals can help shed some light on their concept. According to Goldemberg et al., equity encompasses access to resources, services, and opportunities within all countries and among them. Economic efficiency refers to the efficient utilization of scarce natural, human, and technical resources. Environmental soundness means ensuring integrity of life supporting systems so that economic progress respects rather than degrades the natural order. Long-term viability requires evaluation of social actions in terms of their near and far term benefits and costs. Self-reliance goes beyond the narrow idea of self-sufficiency and encourages economic relations, including trade and aid, as long as societal dependence is avoided. Peace, through avoidance of war and lessening of international tensions is advocated so as to free enormous amounts of economic resources from grossly inefficient military use to be allocated for revitalization of the world economy (Goldemberg et al. 1988: 62).

The NGO and Goldemberg et al. frameworks for sustainability depart from the WCED framework in two specifications. First, they engage development as a structural problem of the world political economy. For both, the core problem of development is not merely the provision of basic human needs but creation of social structures that serve the ends of self-reliance and cultural and social integrity. This difference is fundamental — as aid from and trade with the wealthy may foster the goals of these alternative frameworks, but cannot be the principal means of addressing the development crisis, as they are in the WCED model. Second, these approaches conceive the environmental crisis as a social, as well as, a bio-physical one. The NGO and Goldemberg et al. schemes emphasize environmental degradation in terms of social structures with bio-physical implications deriving from the continuation of activities under prevailing social structures. In the WCED report, the relation between social structure and environmental degradation is left ambiguous.

TAKING ISSUE WITH THE WCED INTERPRETATION OF SUSTAINABILITY

Before critiqueing the WCED report, it is important to credit its authors with two key accomplishments. First, the unqualified attachment of an overriding priority to the essential needs of the world's poor in a truly international and prestigious report has been very significant for the poor in developing countries. This has certainly helped the deprived to gain some attention in the overcrowded agenda of national and international priorities from which they were usually elbowed out before. Second, the juxtaposition of the overriding priority of the poor with environmental problems serves to reinforce the priority of the claims of the poor to the world's resources. This is important as there is a real danger that the crisis situation could otherwise have been used to further curtail the poor's access to natural resources.

But alongside these important achievements must be considered several dilemmas raised by the WCED framework. In Table I, the key concepts and values of the WCED, Redclift, NGO, and Goldemberg et al. approaches are compared. What is striking in this comparisons is the presence of some versions of the equity concept in all frameworks except the WCED report.

Conversely, economic growth is found only in the WCED's framework. The status given to economic growth by the WCED is disturbing, especially given the fact that economic growth has been found even by mainstream researchers to be ineffective by the mid-1970's and was replaced at that time by a "basic need approach" (Lele, 1991: 614).

But the WCED report, using old logic, insists on reviving economic growth and on increasing per capita income.

> "[A]bsolute poverty in developing countries ... has been aggravated by the economic stagnation of 1980's. A necessary but not a sufficient condition for the elimination of poverty is a relatively rapid rise in per capita income in the Third World. It is therefore essential that the stagnant or declining growth trends of this decade be reversed." (WCED,1987: 50).

CHART I

A COMPARISON OF SUSTAINABLE DEVELOPMENT FRAMEWORKS

WCED REPORT:

* EQUITY (basic needs)
* POPULATION & POVERTY
* ENVIRONMENT & RESOURCES.

REDCLIFT:

* SUSTAINABLE LIVELIHOOD THINKING
* POLITICAL ECONOMY OF DEVELOPMENT

N.G.O.:

* INTEGRITY (Cultural & social)
* EQUITY (access + emancipation)
* NON-VIOLENCE
* ERROR-FRIENDLINESS
* ECOLOGY

GOLDEMBERG ET AL.:

* EQUITY
* ECONOMIC EFFICIENCY
* ENVIRONMENT & RESOURCES
* SELF-RELIANCE
* PEACE

Though in its initial discussion, the WCED report defines development in term of satisfaction of basic needs, the main theme of the Commission is economic growth. Effectively, need satisfaction becomes a rationale for additional economic growth. But development is arguably much more than the economic growth. It should encompass ideas of equity (need satisfaction should be achieved through just and equitable means), self-respect, and harmony (including social harmony as well as harmony with nature). Development thinking that mainly emphasizes economic growth, even for satisfaction of basic needs, will necessarily lead to social and environmental conflicts. Capitalism or state-capitalism are antithetical to sustainable development because neither the market mechanism nor the state bureaucracy are geared to integrate equity and justice as priorities. However, in both of these systems it is possible to satisfy basic needs through economic growth.

Lele argues that economic growth by itself can not lead to environmental sustainability nor to the removal of end poverty. Indeed, he suggests that the converse is worth trying, namely policies that serve to poverty, restore environmental balance, and generate employment may lead to a rise in GNP and in per capita income (Lele, 1991: 614).

SUB-PRIORITIZATION OF POVERTY AND EQUITY

Goldemberg et al. define equity in terms of resources, services, and opportunities. The NGO report, through the solidarity principle defines equity in terms of access, distribution, and exchange. Both frameworks further associate equity with empowerment and participation of marginalized classes. Redclift defines equity in terms of participation of the poor in decision making. In the WCED report, the idea of equity is not addressed in detail. Two essentially economic elements — satisfaction of basic needs and rethinking consumption standards — are given primary attention.

A second shortcoming of the WCED's concept of sustainability is that it concentrates on poverty in order to stop physical (ecological) degradation. Physical sustainability is threatened by poverty and inequity, according to the report (WCED,1987: 43). But this mind-set necessarily reduces the problem of poverty to the satisfaction of basic needs so as to preserve (ecological) sustainability. The implicit logic is that the satisfaction of basic needs will curtail resource gouging by the poor and then sustainability can be secured. But such logic blames the victim instead of focussing on root causes; and it neglects humane concerns like equity, self-respect, peace, and harmony as necessary conditions in their own right for achieving true sustainability.

SUSTAINABILITY DEVOID OF DEPTH AND RANGE

The neglect of social elements like political economy, cultural and social integrity, non-violence, peace, and self-reliance which are critically important especially in the context of developing countries gives the struggle for sustainability a shallow and vacuous meaning. Consideration of the political economy of development will point out the need to overhaul present international, national, and local institutions and the need to involve people everywhere in decision making. (Redclift, 1987: 35-36). Social sustainability, in the sense of the sustainability of life affirming values and structures, would require development to be socially and culturally compatible. To make development a continuous and endogenous process, it should have self-reliance as a guiding element. Error-friendliness is a neglected value in the WCED report. It can be an important guiding principle in finding alternatives to continued human quest for high-tech fixes to social problems. These elements give depth and breadth, to development, while addressing problems of poverty and environmental degradation. Unfortunately, this dimensionality is lacking in the WCED approach.

DEMOCRATIZING DEVELOPMENT: CONSENSUS AND EMPOWERMENT

Two other concepts of critical importance for successful sustainable development in developing countries are absent in WCED thinking. Recent experiences in almost all countries suggest that the present model of democracy -- democracy-by-majority -- effectively means conflict of diverging political and economic factions. Governance in this model derives from the

clash of interests with the result, at any point in time, determined mostly by the political and economic power of confronting interests. In addition to neglecting the poor and powerless in society, this model obviates long-term and broader social interests. Thus, effectively, democracy-by-majority has become of little value in achieving sustainability.

This raises immediate and basic concerns for developing countries as their future lies in decentralized technological, economic and political systems facilitating truly sustainable development. This future will require democratization of the development process itself down to the most elementary operational level. Here, two concepts become important — empowerment and consensus. Empowerment means making people and their organizations capable of designing, evolving, choosing, upgrading, and managing development strategies and policies. In the concept of consensus, the starting point is the interest of community or society and not individual or group interests. Consensus is built by a process that gives equal scope and priority to society's interest and encourages all members to take responsibility together for their future.

POLITICAL PROBLEMS WITH THE WCED CONCEPT OF SUSTAINABILITY

THE DANGER OF AMBIGUITY

Ambiguity in the WCED interpretation of sustainable development on the matters of equity, democratization, and political economy can partly be attributed to political expediency. On controversial matters such as these, the Commission seems to have concluded that large institutional support can only be gained by compromise and moderation. And in a certain sense this has proved correct. By avoiding conflict, the WCED has been able to secure, as Lele has noted, the support of mainstream agencies like the World Bank (WB), International Monetary Fund (IMF), and the General Agreement on Trade and Tariff (GATT) which have already adopted the "new rhetoric" (Lele, 1991: 607).

Co-optation at the International Level

But acceptance of sustainability by these agencies can perpetuate the status quo and preserve economic control of the dominant world interests instead of ensuring environmentally sound and socially meaningful development. At the 1992 UNCED meetings, rich countries of the North prevailed over developing countries of the South not only in maintaining but in increasing role of the World Bank in environment - development conflicts. The World Bank's subsidiary Global Environmental Facility was assigned primary institutional responsibility for North - South negotiations on the environment. In this and other institutions, the rich North has near-monopolistic control. Now countries from the South are afraid that the environmental implications of sustainable development can become still another basis for controlling the economic and social policies of developing countries. They are also afraid that the North will use its increased economic and political power to impose its version of sustainable development on the South and in effect make the South forgo its right over use of resources to develop in its own terms. In the light of the North's profligate misuse of the environment and people in the South, the prospect of sustainability being used in this way breeds skepticism, if not cynicism, in the Third World.

These fears do not appear to be ill-founded. Continued elevation of economic growth and free trade to the status of ideals in the WCED interpretation will suggest that the Northern control is anticipated. As Shrybman points out, free trade will benefit the North and further increase its control and enjoyment of the largest share of natural resources at cheap prices. GATT and related policies encourage the transfer of dirty industries to the South in exchange for economic growth (Shrybman, 1990: 31-32). And as Byrne et al. observe, the oft-cited success story of the Asian tigers is industrialization brought with increased economic growth and accelerated environmental damage (Byrne et al. 1991: 6).

Co-optation at National Level

Equally serious is the potential for co-optation of sustainability by national governments. It is quite clear that irrespective of political system, all governments are subject to significant influence by dominant economic and political interests in their countries. The pressure of dominant interests leads governments to sub-prioritize, if not sacrifice, the concerns of sustainable development. Sub-prioritization is reflected in the near-total impossibility of a sizable increase in the gasoline tax by any government in the U.S. It is also reflected in weak and undefined pollution standards prevalent in many developing countries in response to pressures from industrial lobbies.

An additional but neglected cooptation threat in the literature is the adoption of sustainable development as a rhetorical device to blur conflicting issues and to blunt resistance of victims of environmental degradation. With large shares of southern resources controlled by dominant interests, sustainability can be used to distract attention from the economic and political inequality that characterizes natural resource access and distribution.

NARMADA DAM : WHOSE DEVELOPMENT AND SUSTAINING WHAT ?

Two Diverging interpretations

Saradar Sarovar, a dam project on the river Narmada in central India is a classic example of the political use of ambiguity in sustainable development to justify socially exploitative results. The proposed dam will be 3970 feet wide and 455 feet high and its reservoir will be 125 miles long. Saradar Sarovar is the first dam of the ambitious Narmada Valley Development Project involving eventually, 30 major dams and 3000 medium and minor irrigation schemes (NYT, 1992: B10). Proponents hail this project as a life-line for development of the state of Gujrath and an excellent example of a development project adhering to the sustainability criterion. It is a hydro-electric project, a source of renewable energy which can provide electric power for irrigation and industry, both of which are absolutely essential for economic growth of the region. The Narmada project is hailed as a model of development for a country like India. It will irrigate thousands of acres of arid land and hence will be a great boost to peasant agriculture production as well as the regional commercial economy.

In sharp contrast, people affected by the dam and grass-root organizations working with them claim that the project will doom not only the submerged area but also the newly irrigated areas. According to them, the benefits are overblown and costs are minimized or neglected

(Patkar, 1988: 30). These groups argue that equivalent electrical power can be made available through the promotion of end-use efficiency measures like compact fluorescent lamps and that similar irrigational benefits can be obtained through smaller irrigation projects and land and water conservation strategies that require less investment and avoid the monumental environmental, social, and human costs involved in this mega-project (Sant, 1992). They point out that the costs in irrigated areas in terms of water-logging, soil-acidification, and health hazards are substantial. Most important are the human costs suffered by more than 100,000 rural and tribal people to be displaced by the dam. These human beings have skills and economic activities appropriate to their present environment. Their social and cultural values, traditions, and institutions are rooted in their present life-styles and their relation with natural environment. Once uprooted from their homeland, they are not just economically but also politically, socially and culturally vulnerable. Compensation in cash or in kind cannot eliminate the vulnerability of those who will be dispossessed by the dam and thrust into an alien social and ecological environment.

Polarization of Interests

Opposing the dam project is a loose coalition of grass-root level organizations from the project area and from other areas, national level non-government organizations (NGO), professional organizations, and NGOs from other countries. Supporting the project is a coalition of the state governments of all the three states affected and served by the dam, the central (federal) government of India, and the World Bank. The World Bank, whose subsidiary Global Environmental Facility (GEF) was entrusted with the task of overlooking world-wide implementation of sustainable development, is giving $450 million for the dam and another $456 million for related canal work (NYT, 1992: B10). The Government of India, which has been one of the most vocal critics of the Northern policies and multilateral institutions on sustainability issues in many international fora is propitiating the World Bank for continuation of financial support of the project. The state governments and political parties have used organizational and political means to whip up hatred and frenzy and police power and bureaucratic tactics to intimidate local people agitating against the dam. All of this is taking place in the name of sustainable development.

The Morse Report

Pressures from local tribal people and other organizations supporting them compelled the World Bank to appoint an independent review commission in September 1991 under the direction of Mr. Bradford Morse, former head of United Nations Development Program. The commission concluded in its 358 page report that:

> [W]e can not put together a list of recommendations to improve resettlement and rehabilitation or to ameliorate environmental impact, when in so many areas no adequate measures are being taken on ground or are even under consideration ... [B]enefits tend to be overstated, while social and environmental costs are frequently understated. Assertions have been substituted for analysis" (Morse et al. 1992: xxiv).

Instead, the commission recommended that,
[W]e think that the wisest course would be for the bank to step back from the Projects and consider them afresh. The failure of the Bank's strategy must be acknowledged (1992: xxx).

Despite the conclusions reached by the Morse commission, the World Bank has decided to continue its funding of the project. Ambiguities in the interpretation of sustainability and its alignment with the goal of economic growth permit the World Bank and Government of India to join in promoting this mega-energy project. This is being done with predictable complement of environmental studies and impact analyses, all with total disregard of social sustainability and the human costs involved.

CONCLUSION

The greatest danger to environmentally sound, socially meaningful, and culturally reinforcing development is the continued attachment to an ideology of economic growth and managed consensus. The task of global development is not growth but to ensure that the humanity as a whole can survive and prosper materially and culturally. But even more fundamental, the aim of global development must be the pursuit of human aspirations of integrity, equity, self-reliance, peace, and harmony. Sustainable development may be one of our most important opportunities to humanize our relations with one another and with nature. In his closing speech at the Rio Conference by U.N. Secretary General Boutros Boutros Ghali aptly defined the true challenge of sustainability:

> It is no longer enough for man to love his neighbor, he must now also love the world. Beyond man's covenant with God and his social contract with his fellow men, we now need an ethical contract with nature and the Earth.(Khor, 1992: 1).

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TRANSCENDING EFFICIENCY'S DILEMMA: A VIEW FROM THE COADAPTATIONIST POSITION[1]

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Today's rising energy, environmental, and developmental issues--such as disappearing fossil fuels resources, global warming, and expanding world populations--suggest that technology, nature, and humanity are on a collision course. An emerging group of critical thinkers are arguing that the best way to deal with these concerns is by integrating a broader notion of efficiency into our technological designs and arrangements. One of these thinkers, Andrew Feenberg (1992: 312), suggests that "such changes would enhance efficiency in broad terms by reducing harmful and costly side-effects of technology." In this view, genuine efficiency is achieved only by incorporating the needs of both humanity *and* nature within our technological designs and arrangements at the outset instead of addressing those needs as afterthoughts. For example, narrow efficiency advocates attempt to solve our growing social and environment problems arising from a transportation system that favors the private automobile through increased fuel efficiency and wider roadways. Broad efficiency advocates, on the other hand, suggest that a better solution would involve restructuring of our urban organizations such that more socially and environmentally benign mobility forms like mass transit, the bicycle, and foot transport play an expanding role.

Broad efficiency arguments are grounded in what I call the *ideology of coadaptation*, or the *coadaptationist position*. Recognizing that there are limits to all action, this position understands that our technological choices have long term affects on both humanity and nature and that undesirable side-effects are not easily mitigated, if mitigatable at all. Adverse feedback such as like global warming, acid rain, and urban smog and gridlock may be deferred by 'perfecting' existing technological designs at the margins, but it cannot be avoided. Unfortunately, policy positions grounded in the coadaptationist position are consistently frustrated by the deceptively appealing premises provided by what I call the *antinomy of Darwinian rhetoric*. With Andrew Feenberg (1981: 5), I use "antinomy" to signify the Hegelian notion of "the ever widening gap between subject and object in modern culture."

This paper explores the premises of Darwinian rhetoric and the ideology of coadaptation in order to provide a theoretical framework for evaluating the 'efficiency' of policy positions. In the first section, I discuss both sides of Darwinian rhetoric's antinomy: the *ideology of conquest*, or *the conquest position*, and the *ideology of adaptation*, or the *adaptationist position*. In the second section, I use arguments from the American Council for and Energy-Efficient Economy (ACE[3]) and the National Academy of Sciences (NAS) to show how policy

positions that give priority to narrow interpretations of efficiency over broader, genuinely sustainable ones play into the hands of the ideology of conquest. Such policy positions help defer humanity's energy, environmental, and developmental concerns for solution by future generations, and in so doing they threaten foreclosure on currently available developmental paths and leave humanity vulnerable to such things as the nuclear option as we begin to run out fossil fuels. In closing, I give an outline of the ideology of coadaptation, or coadaptationist position. By defining efficiency in broad terms, this world view transcends efficiency's dilemma and offers humanity hope for continued development.

THE ANTINOMY OF DARWINIAN RHETORIC

Darwinian rhetoric is a biologized mixture of nineteenth century theology, philosophy, economics, and evolutionary theory. It is informed by three principles of evolutionism. First, its *principle of progress* provides ideological ground for arguing that the next generation of a particular technological form will be necessarily better than the last. New, more 'fit' versions of existing technologies are always imminent. Second, its *principle of transformation* asserts that hum^n and technological forms are infinitely plastic. This principle gives ground to the belief that humanity will continue to adapt to its changing environment or it will continue to develop technologies to fill in the gaps. Finally, the *principle of competition* provides the 'natural law' that drives the developmental process. In the heat of competition, technological lineages are being perfected continuously. Those forms that survive are *necessarily* the most 'fit'--that is, they represent the best possible solutions for problems presented by the external environment.

Darwinian rhetoric's three principles give rise to an antinomy. One side sees technology as under human control and absolutizes humanity's role as the *subject* of its own development. This is the side of the ideology of conquest; arguments from here take the conquest position with respect to nature and social organizations. The other side of the antinomy sees technology as an autonomous unfolding and absolutizes humanity's role as the *object* of evolutionary processes. This is the side of the ideology of adaptation; and arguments from here take what I call the adaptationist position with respect to nature, technology, and social organizations.

The ideology of conquest has its roots in Thomas H. Huxley's vulgar Darwinian science. It views technology as that product of human creativity that protects us from the clutches of nature. Motivated by Huxley's notion that organic evolution is not *necessarily* a forward moving process--that is, extinction is a real possibility-- the ideology of conquest argues that humanity can only guarantee its place at the pinnacle of evolution by gaining a controlling hand in its "struggle for existence" with nature. Under this view, humanity is the object of not necessarily benevolent forces locked within as external (i.e., alienated) environment. Technology is the key by which we gain access to manipulate nature's forces for our own purposes. The goal is to dominate nature before it has a chance to dominate us. Given that the conquest position views success in this endeavor as all but certain, it provides ideological space for humanity to effectively ignore the adverse side-effects arising from intermediate

technological forms. After all, more efficient versions of existing technologies are always imminent.

The ideology of adaptation, on the other hand, has its roots in Herbert Spencer's *Synthetic Philosophy.* This view sees technology as an autonomous unfolding slowly transforming our world into a realm of artificial objects to which we must either adapt continuously or else we will perish. Although this position agrees with the ideology of conquest that human beings are the object of not necessarily beneficent evolutionary forces, the ideology of adaptation takes an opposing stance to the ideology of conquest with respect to human and technological development. The point of departure is simple. The ideology of adaptation does not see such development as necessarily under human control. On one level, this position sees both technology and human beings as objects of evolutionary forces emanating from the external environment. On another level, it sees technology and as the *subjective* tool used by alienated forces to shape humanity and nature alike via the evolutionary 'law' of survival of the fittest and the 'law' of adaptation for which it is named. Given the adaptationist position, we either passively accept the transformation of our world into a set of artificial objects in the name of material progress, or we reject such transformation out of hand and seek a romantic retreat to a more primitive existence.

Under the antinomy of Darwinian rhetoric, issues like global warming either signal technical problems that will be solved by increased human ingenuity, or they signal the need for more developed segments of humanity to halt their 'progress'. The former position is the one actively pursued by groups such as NAS and, however unwittingly, by groups that advocate narrow energy efficiency objectives such as ACE^3. The latter position, the one calling for romantic retreat or fateful resignation, is the one taken by anti-development critics such as Wolfgang Sachs (1990, 1991) and anti-technology critics such as Jacques Ellul (1964). Given that the adaptationist position does not yet represent a danger to continued human development, since it is easily marginalized by the pro-development, pro-technology conquest position, I focus the next section's discussion on the narrow efficiency arguments of ACE^3 and show how it plays into the hands of NAS's ideology of conquest.

NARROW EFFICIENCY: PLAYING INTO THE HANDS OF CONQUEST

Today, environmentalists and policy makers alike tout energy efficiency as humanity's best option for meeting our growing developmental concerns. Even the World Commission on Environment and Development (WCED) promotes this view: "Energy efficiency policies *must be the cutting edge* of national energy strategies for sustainable development, and there is much scope for improvement in this direction" (WCED, 1987: 14, emphasis mine). In their favor, many narrow efficiency advocates recognize that increased energy efficiency is not a cure-all. They see it for what it is, a temporary fix that can buy time for humanity to develop "softer" energy options. But good intentions aside, the reality of narrow efficiency policies is that they play into the hands of conquest. By giving narrow efficiency policies "cutting edge" status, monetary and intellectual resources are channeled away from the pursuit of broader

efficiency goals that could be achieved through more environmentally benign and socially equitable technological designs and arrangements.

ACE³'s *Energy Efficiency: A new agenda* (1989) is a case in point. After suggesting that "[r]enewable energy technologies are either too costly or can make only a small contribution to reducing . . . environmental problems over the next two decades," ACE³ argues that the U.S. should seek increased use of more efficient fossil fuel technologies already in existence because "these technologies can ease the transition to renewable energy sources" (ACE³, 1989: 19). In the mean time, ACE³ suggests that such things as "new coal burning technologies will be needed." As ACE³ sees it, the expected proliferation of these new fossil fuel technologies is actually a blessing for the U.S. in that is offers "a practical means of achieving [three] national goals" (1989: 1). One, the proliferation of such technologies will allow the U.S. to protect its environment. Two, it will strengthen U.S. national security. Finally, it will create more U.S. jobs and promote economic security by making U.S. industries more competitive in world markets.

The logic of ACE³'s efficiency "agenda" is appealingly simple. Though our world's fossil fuel supplies are finite and their continued use is environmentally undesirable, the life of these fuels can be extended and their adverse effects mitigated through appropriate design improvements in the technologies that use them. Couple these two facts with an increasing global demand for fossil fuels and a deteriorating global environment and one has a prescription for substantial economic gain. As fossil fuel supplies become increasingly scarce, worldwide demand for more efficient fossil fuel technologies will rise, and countries that have positioned themselves well in the 'efficiency' market will stand to reap substantial economic and political profits. Indeed, Amory Lovins (1991) estimates that the efficiency market will eventually amount to a trillion dollars a year, and that is a large sum for nations that successfully exploit it. Hence, it is no wonder that U.S. policymakers like the sound of narrow efficiency arguments. But such calls for efficiency run the real danger of foreclosing on humanity's genuinely sustainable energy and developmental options. A brief analysis of NAS's (1991) *Policy implications of greenhouse warming--synthesis panel* emphasizes this point.

In its "findings and conclusion," NAS (1991) suggests a six-step policy position that provides a classic example of just how the narrow efficiency movement plays into the hand of conquest. In step one, NAS argues that the U.S. should seek offsets in greenhouse gas emissions by, among other things, perfecting existing fossil fuel technologies. As with almost every narrow efficiency argument, this step is particularly inviting in social organizations concerned with maximizing material well being. Upon closer examination, however, this step seems almost malignant. In the area of electrical generation, though not ruling out the need for alternative energy sources altogether, NAS emphasizes the need for 'perfecting' of our existing system. Its preference for domineering technologies of the conquest mold is quite clear: "[a]lternative energy technologies are unable currently or in the near future to replace fossil fuels as the major electricity source [in the U.S.]" (NAS, 1991: 75). In addition to 'safe' nuclear power plants (an oxymoron?), NAS's global warming 'solution' calls for the

development of more efficient coal and natural gas systems, more fuel efficient homes, buildings, and automobiles, and improved CO_2 sink technologies, such as reforestation.

Step two calls for the development of technologies to lessen the effect of global warming on human and natural systems. NAS calls this step, "Enhancing Adaptation to Greenhouse Warming" (NAS, 1991: 76). It is this step that gives NAS's Darwinian rhetoric away. Specifically, NAS argues that the U.S. should do three things in this area. First, it should develop agricultural plant and animal species better able to deal with changing climates to ensure ample food sources. Second, the U.S. should develop new engineering techniques to ensure adequate water supplies and to secure coastal areas from rising ocean waters. Finally, the U.S. should develop techniques that enable it to guarantee diversity in nature. These measures, according to NAS, will require the development of new climatic monitoring devices to enhance our knowledge of weather patterns and climate changes due to global warming. It seems that NAS has more confidence in humanity's ability to predict the weather than in its ability to develop environmentally benign, renewable energy sources. On the surface step three, "Improving Knowledge for Future Decisions," seems benign enough but upon closer examination it is not. Knowledge improvements are not suggested in order to support the movement of humanity toward more environmentally sound developmental pathways. On the contrary, they are "needed for identifying adaptations that will be needed in the future" as the global warming increase (NAS, 1991: 79).

Step four, "Geoengineering Options," is particularly frightening. It calls for the U.S. to evaluate geoengineering options that might be used in the event that "other efforts to restrain greenhouse gas emissions fail" (NAS, 1991: 81). This option includes such things as screening incoming solar radiation by depositing "dust or soot in orbit about the earth on in the atmosphere," changing cloud patterns through the introduction of "particulate matter," and through the development of bioorganisms that absorb CO_2 (NAS, 1991: 81). Finally in step five, "Exercising Leadership," NAS suggests that the U.S. seek a leadership role in the area of voluntary population control and that it must "participate fully . . . in international agreements and in programs to address greenhouse warming" (1991: 81-82). This is perhaps NAS's best option--that is, if we skip the other steps. After all, if the U.S. promotes such things as species adaptation and geoengineering, then at least two questions come to mind. First, what might the adverse environmental side-effects from large scale adaptation of domestic and natural species look like? And second, what might the side-effects be when nations start manipulating their individual weather patterns through geoengineering measures?

A recap of the logic behind NAS's policy steps will make it clear that their greenhouse policy is informed by Darwinian rhetoric. According to NAS, our current technologies are the best evolution has to offer humanity. Adverse side-effects from their operation, such as global warming, are but minor inconveniences that can be corrected with marginal adjustments to our current social structure. In others words, narrow efficiency improvements can slow global warming without major disruptions in the U.S. economy. As we pursue such improvements, science and engineering will have time to develop new technologies that will allow humanity to adapt to the increasingly adverse side-effects from continued fossil fuel use. Over time,

though, the effects of global warming will get worse, but our ability to gather data and knowledge will allow us to identify new methods and construct the technologies necessarily to deal with new contingencies as they arise. Eventually, we will have enough knowledge to technologically alter the earth's natural processes and neutralize global warming and other adverse side-effects from continued fossil fuel use.

But this line of argument is totally absurd for at least two reasons--one practical, the other philosophical. On a practical level, fossil fuel driven technologies are doomed to extinction no matter how much we succeed in improving their efficiency. Our world contains a finite amount of fossil fuel resources. And, given the natural limit to all actions, our narrow efficiency resources are equally finite. Once both are exhausted, we will need alternative fuel driven technologies. But if we do not pursue such alternatives now, our future options will be quite different from what they are today. As global warming increases and fossil fuels and time become increasingly scare, the nuclear option and its attending authoritarian social structure that Lovins (1979) warned of in *Soft Energy Paths* becomes easier to swallow. On a philosophical level, NAS's logic perpetuates the myth that humanity can effectively co-opt all of nature's powers. This line of argument is clearly that of the ideology of conquest, and if we continued to follow it, then it will surely lead humanity as we know it to certain destruction. Either the environment that sustains us will be destroyed, or technological choices will be made that leave us less than human. What we must recognize is that certain functions are best performed by nature itself. Therefore, technologies that incorporate nature's needs and functions within their initial designs are humanity's best hope for continued development.

THE COADAPTATIONIST POSITION: TRANSCENDING EFFICIENCY'S DILEMMA

When speaking of human development, both in developed and Third World nations, the coadaptationist position argues for a broad interpretation of efficiency. Technologies conceived under this position are unlike those conceived under Darwinian rhetoric. *Darwinian technologies* seek domination of the social and natural environment in name surplus profit narrow interests. *Coadaptationist technologies*, on the other hand, seek harmony between social components and the natural environment in pursuit of broad social goals and environmentally sound development.

In practice, Darwinian technologies are design and constructed in isolation by individuals or small groups with little regard for organizational and environmental congruity. Once developed, they are inserted into the social and environmental milieu to compete for space with existing structures. 'Successful' technologies are those 'fit' enough to force changes in the social organization that insure their continued 'survival'. True to Feenberg's concepts of autonomization and positioning which he criticizes (Feenberg, 1991: 186-188), Darwinian technologies become dominant by realigning the existing social organization in such a way that social actors come to believe that they cannot survive without them. Perhaps the most 'successful' Darwinian technology is the private automobile. What began as a toy for the rich at the turn of the nineteenth century has to date uprooted countless miles of country side, transformed many urban centers into waste lands, and is now threatening to raise world

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THE COADAPTATIONIST POSITION: TRANSCENDING EFFICIENCY'S DILEMMA

When speaking of human development, both in developed and Third World nations, the coadaptationist position argues for a broad interpretation of efficiency. Technologies conceived under this position are unlike those conceived under Darwinian rhetoric. *Darwinian technologies* seek domination of the social and natural environment in name surplus profit narrow interests. *Coadaptationist technologies*, on the other hand, seek harmony between social components and the natural environment in pursuit of broad social goals and environmentally sound development.

In practice, Darwinian technologies are design and constructed in isolation by individuals or small groups with little regard for organizational and environmental congruity. Once developed, they are inserted into the social and environmental milieu to compete for space with existing structures. 'Successful' technologies are those 'fit' enough to force changes in the social organization that insure their continued 'survival'. True to Feenberg's concepts of autonomization and positioning which he criticizes (Feenberg, 1991: 186-188), Darwinian technologies become dominant by realigning the existing social organization in such a way that social actors come to believe that they cannot survive without them. Perhaps the most 'successful' Darwinian technology is the private automobile. What began as a toy for the rich at the turn of the nineteenth century has to date uprooted countless miles of country side, transformed many urban centers into waste lands, and is now threatening to raise world

atmospheric temperatures by altering the earth's atmospheric mix. And the automobile and its proponents have done these things in such a way that we view these changes as irreversible, natural products of evolution. The beauty of coadaptationist technologies, on the other hand, is that they promise to meet humanity's expanding social and environmental concerns without the adverse side-effects that accompany Darwinian technologies. In other words, the coadaptationist position does not require humanity to sacrifice the original promise of technology--that is, to liberate humanity from everyday toil--that continues to make Darwinian rhetoric so deceptively appealing.

Taking its cue from the evolutionary theory of Levins and Lewontin (1985) and Maturana and Varela (1991), the coadaptationist position is grounded in three principles. I call the first principle, the *principle of ambivalence*[2]. It argues that although our world is a structurally determined system, our future is always open to new developmental pathways. Only in hindsight, and to an independent observer, does the development of organic and technological forms appear as linear extrapolations from their inception. In reality, every moment of continued existence represents the possibility of a new developmental direction. Second, the *principle of proportion* maintains that organization has ontological priority over structure. In other words, the particular structures that make up our social systems can change over time without those systems losing their organizational integrity. This means that the structures currently defining our social organizations do not *necessarily* represent the best that 'nature' has to offer. On the contrary, new, more humane, and environmentally sound technological structures are not only possible, they are desirable.

Finally, the *principle of conservation* asserts that humanity's primary goal must be the maintenance of its organizational integrity through time, and that such integrity can only be guaranteed if we remain structurally coupled to our environment. This means that we must not seek to dominate our surroundings. Rather, we must seek social organizations constructed with flexible technologies that harbor the widest possibilities for structural change. Flexible organizations are more apt to survive and progress over time that more rigid ones. Darwinian technologies like large-scale electrical power and automotive centered transportation systems are proving this point today. Hence, as it becomes increasingly apparent that Darwinian technologies are falling short in fulling the original promise due to the unforeseen and undesirable side-effects of their operations, the ideology of coadaptation's position that humanity can realize that original promise through a new relationship between technology, nature, and humanity becomes particularly inviting.

In this light, the coadaptationist position argues that efficency's dilemma can be transcended through a broader interpretation of its meaning. Metaphorically speaking, just as efficiency in living organizations is said to increase as organismic lineages change direction of branch off in new lineages with more flexible structures, our social organizations can be said to become more efficient as we transform our Darwinian technological structures into more coadaptationist forms that better couple each other and their changing environment. The coadaptationist position therefore rejects narrow calls for efficiency because such calls too often produce policies that play to particular human ends and particular Darwinian structures. For example, narrow efficiency advocates argue that environmental problems associated with

fossil fuel driven automobiles can be corrected through new engineering advances. But the coadaptationist position argues that if humanity's organizational goal is easy geographical movement, then that movement is more efficiently achieved through the adoption of less domineering means such as mass transit, home based work via computer networks, and/or better planned cities with higher densities. The point to remember here is that by defining efficiency broad terms, the coadaptationist position shows that human development does not have to stop or retreat. Rather, it shows us that an environmentally sound, socially equitable technological society is possible.

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[1] Author's Note: this article applies concepts developed in my (1992) MA thesis, *The Ideology of Coadaptation: Toward a Non-Domineering Model of Technology*, San Diego State University. I would like to thank my thesis chair Andrew Feenberg for his many contributions in that endeavor. Additionally, I would like to thank my colleague Willett Kempton at the Center for Energy and Environmental Policy at the University of Delaware for comments on an earlier draft.

[2] See Andrew Feenberg (1991), *The Critical Theory of Technology*, New York: Oxford Univ. Press, 42-44, who uses the concept of ambivalence to denote "the possibility of bootstrapping" from our capitalist industrial society to a freer, less technologically domineering socialist existence.

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URBAN SUSTAINABILITY IN AN INDUSTRIALIZING COUNTRY CONTEXT: THE CASE OF CHINA

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Since the 1970s, Asian developing countries have experienced rapid economic growth. While the world economy grew at an inflation-adjusted rate of 2.1 percent annually during 1977-1987, 37 Asian developing countries registered an average annual growth rate of 4.8 percent (Byrne et al., 1992:22). China's performance was even more impressive, with the country growing at an average annual rate of 9.6 percent during the last decade (CSSB, 1990:3). Compared with the world economy, China's economy grew nearly five times faster.

Historically, rapid economic growth in developing countries has often been accompanied by even more rapid growth in commercial energy use. This trend is evident in the recent economic growth of Asian developing countries. While the rate of energy consumption in the rest of the world increased an average of 3.1 percent annually during 1977-1987, Asian developing countries expanded their energy use by more than 7 percent (Byrne et al, 1992:2). China's energy consumption grew at an annual rate of 5.2 percent during that same period (CSSB, 1990:149).

Successful GNP growth among Asian developing countries has been accompanied by a second, related tendency. As these countries enjoyed economic growth, they found themselves experiencing high level of energy-induced environmental degradation. The negative environmental effects of Asian economic growth are dramatically visible in large cities where industry and populations are heavily concentrated and where large amounts of fossil fuel are consumed.

This is particularly true in China where industrial activity and commercial energy use facilities are located in or near a few large cities. As a result, China's large urban populations are exposed to a multitude of air pollutants, including sulphur dioxide (SO_2), nitrogen oxide, carbon monoxide, volatile organic compounds, fly ash and other suspended particulate matter (SPM). A study of global air quality (WHO/UNEP, 1987), for example, reported that the ten cities in its survey with the highest levels of suspended particulate matter were all in Asia, and five of these cities--Shenyang, Xian, Beijing, Shanghai, and Guangzhou--were in China. Further, emissions of a second pollutant--sulphur dioxide--were likewise concentrated in Asia with five Asian cities among the ten highest. Three of the five Asian cities--Shenyang, Xian, and Beijing--were Chinese. The measured levels of SPM and SO_2 in China's five cities exceed WHO health guidelines, indicating that continued emissions at those levels threaten the health of China's urban populations.

Suspended particulate matter and sulphur dioxide are both by-products of coal combustion and coal has been the major energy source for fueling development in Asian countries. This is especially true for China which depends on coal for more than three-fourths of its commercial energy use (CSSB, 1990:149). When this fact is coupled with China's requirement for further economic expansion to meet the growing needs and desires of its population, it is clear that China faces difficult, even self-contradictory, choices of economic growth versus social health and sustainable relations between society and the natural environment. The self-contradictory character of these choices can be traced directly to the growth-oriented development path that currently guides the nation. It is our argument that a national transition to a sustainable mode of development is needed. This will benefit cities because they are the nexus where the nation's development, energy, and environmental choices are realized. Through a national transition to sustainability, China's cities can improve human health and environmental quality while maintaining their role as the key contributors to the national economy.

Our analysis is presented in three steps. First, a conceptual framework is developed to contrast the major economic, technology, energy and environmental assumptions between conventional development with a new, sustainable one. Then, using five of China's cities--Beijing, Guangzhou, Shanghai, Shenyang and Xian--as case examples, it demonstrates that urban environmental degradation in China, like many Asian countries, is directly attributable to the pursuit of economic growth under the conventional development model. Finally, using the sustainable development model, it lays out a policy agenda that promises to move China toward environmentally sound urban development.

Conventional vs. Sustainable Urban Development: A Conceptual Framework

In the history of industrialization, cities have played a decisive role in economic development. According to Byrne et al. (1985:102):

> The key to this role was the complementarity between industrial technology and urban form. This complementarity was so extensive and so supportive of economic growth that the phenomena of industrialization and urbanization became virtually inseparable.

Moreover, it became widely accepted that industrial progress depended upon increased use of energy. Cities were, thus, characterized as both centers of industrial production and of energy consumption. As Odum and Odum (1976:153-154) put it,

> Western cities became centers of growth-promoting activities that accelerated the use of resources for growth. The system became specialized in the uses of new energy sources.

Air pollution "first became evident during the industrial revolution, when many cities in Europe and the United States were covered with black shrouds of coal-driven smoke." (French, 1990: 99) But this air pollution was not generally viewed as something negative; rather, it signaled within the industrial interpretation of social development that a city was prospering:

> [T]he smoking factory chimney, which polluted the air and wasted energy, whose pall of smoke increased the number and thickness of natural fogs and shut off still more sunlight - this emblem of a crude, imperfect technics became the boasted symbol of prosperity ... the reek of coal was the very incense of the new industrialism. A clear sky in an industrial district was the sign of a strike or a lockout or an industrial depression. (Mumford, 1934:168-169)

Under the conventional model of development, urbanization, industrialization, massive energy use and pollution are concomitant. This development orientation makes wealth creation the primary objective, stable energy supplies and industrial production technology the essential means, and regards the environment as a free resource to be exploited for its commodity value. Many developing countries have reproduced (in modified form) this model of urbanization.

In the conventional development model, there is typically a direct spatial tie between cities and industrialization. Cities provide industry with convenient modes of transportation and communication, easy access to skilled labor, and plenty of consumers. Besides these spatial ties, the conventional development model links cities and industrialization in terms of economic ideology, energy and technological system design, and environmental orientation.

Generally, the ideology of the conventional model reflects its over-arching goal of wealth creation. The urban economy is commodity-based and consumption-driven. Urban systems operate to produce more goods to meet escalating growth in population and consumer demand. To speed up the production, resources are intensively used and valued in terms of economic priorities. That is, economic costs, not broader social costs, are the primary concern under the conventional development model.

Viewing ever increasing energy consumption as a prerequisite to economic growth, the conventional development model emphasizes stability, reliability, and optimization of energy supply in the design of energy and allied technology systems. It considers adverse social and environmental impacts as external to energy decisions. Energy system goals are couched almost exclusively in terms of supply. The conventional model argues that countries must not only secure abundant and cheap energy resources, but they must also ensure continuing supplies by diversifying the sources used. The primary means for achieving these goals is through large-scale, centralized and capital-intensive technological systems. Technological choices are governed by economic concerns, determined by energy demands, and driven by industrial infrastructure needs.

In the conventional development model, environmental values are framed entirely within an industrial context. The environment is viewed as an inexhaustible source of commodities and reservoir for the absorption of industrial wastes. The economic value of natural resources is purposefully kept low to spur rapid growth, and pollution is treated as an unavoidable side effect of economic progress. This model produces urban economic systems that are resources-intensive and highly polluting in order to keep production costs down. Ironically, this model produces urban environmental degradation as a condition of social advance.

Recent interdisciplinary efforts among social scientists, technologists and environmentalists to conceptualize an alternative to this prevailing growth-oriented, resource-intensive, environmentally-destructive path to industrial urban development have coalesced with the articulation of a sustainable development model. The sustainable development model focuses societal emphasis away from short-term economic gain and environmental exploitation and toward long-term social and economic viability and environmental integrity. It moves societies away from exclusively economic considerations and toward broader social and environmental concerns. Within this framework, future as well as present needs are integrated into developmental considerations. The World Commissions on Environment and Development (WCED) (1987:43,9) synthesized decades of interdisciplinary research with the following description of sustainable development models:

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs . . . Sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technology development, and institutional change are made consistent with future as well as present needs.

Fundamental differences between the conventional and sustainable urban development models can be identified. In Table 1, these models of development are contrasted in their urban, energy, environmental and technological dimensions.

Spatially, the sustainable development model calls for dispersed industrial enterprises rather than concentration. This spatial arrangement reduces urban energy demands and environmental pollution. In addition, as manufacturing decentralizes, urban centers are able to focus on community needs and to relate industrial development to social goals and values. Urban land use, landscape architecture, and building construction under the sustainable model are all sensitive to energy efficiency, resource conservation, and environmental protection. Mass transportation prevails in urban transportation systems, and greater energy efficiency in residential and industrial sectors is promoted.

Ideologically, long-term development rather than short-term growth is the basic goal of the sustainable model. The urban economy is community-based and conservation-driven. Institutions that comprise sustainable systems are responsible for developing energy-conserving and environmentally-sensitive means to achieve desired social outcomes. Recognizing that resources are limited and vulnerable, the sustainable model embraces the goal of coordination in production, consumption and conservation activities. Economic calculations are balanced by social and environmental costs in the concept of sustainability.

Although fossil energy supplies are still needed at this time to boost economic development, efficient energy use and renewable energy resources should form the basis for system development. In the sustainable model, technological flexibility is emphasized and, for this reason, conservation and renewables are given development priority. Social and environmental impacts are treated as internal to energy decisions with energy system goals including social equity and environmental stewardship. The sustainable model calls for an energy system, specifically, and a technology system, generally, that is moderate in scale, decentralized in organization, and user-driven. Technological innovation is guided by the criteria of resource conservation, minimum environmental impact and social equity.

Ecologically, the sustainable view of development recognizes the interdependence between humanity and the environment. Resources are recognized as exhaustible and vulnerable. Environmental impacts thus become a major concern in the pursuit of economic development. Sustainable urban economic systems operate with the aim of enhancing energy self-reliance and maintaining social and environmental quality.

Table 1
CONVENTIONAL VS SUSTAINABLE URBAN DEVELOPMENT MODELS

Conventional Model	Sustainable Model
The Urban System	
* Urban-concentrated industrial localities	* Regionally dispersed industrial localities
* Manufacturing-oriented	* Community-oriented
* Short-term economic growth	* Long-term development
* Commodity-oriented	* Conservation-oriented
* Consumption-driven	* Balance sought between consumption and conservation
* Resources seen as inputs to production system	* Resources seen as limited, vulnerable, requiring stewardship
* Resource-intensive, governed by economic priorities	* Resource-conserving, governed by multiple priorities
* Economic costs are primary	* Economic costs balanced by social/environmental costs
The Energy System	
* Fossil fuel-based	* Alternative energy sources
* Abundant and cheap supply emphasized	* Conservation and renewability emphasized
* Diversify sources of supply	* Reduce energy intensity
* Fuel-based prices	* Social/environmental cost-based prices
* Technology-focused	* Conservation-focused
* Efficiency in economic production	* Efficiency in end-uses
* Scale economies and technological centralization emphasized	* Modularity and technological decentralization sought
The Environmental System	
* Humans dominate the environment	* Humans and environment are seen as mutually dependent
* Environment as an abundant source of commodities	* Exhaustibility of natural resources recognized
* Environmental impacts external to economic choice	* Environmental impacts internal to economic choice
* Rehabilitation-oriented	* Prevention-oriented
The Technology System	
* Large-scale	* Moderate scale
* Centralized system	* Decentralized system
* Infrastructure-driven technology choices	* User-driven technology choices
* Technical decisions governed by economic costs	* Technical decisions governed by social/environmental costs
* Environmental impacts ignored	* Environment-sensitive design

(Source: Adapted from J. Byrne et al., 1992: 26)

The distinctions between the conventional and sustainable development models are fundamental. Reconciliation of economic growth with a healthy environment depends upon which development orientation is chosen. In the following section we analyze the interrelationships of energy, environment and development in five Chinese cities to demonstrate that their deteriorating urban environments are the product of national pursuit of the conventional model of urban development.

Unbalanced Urban Development: A Case Study of Five Chinese Cities

Deteriorating environmental quality in five Chinese cities

International and domestic studies have revealed striking evidence of declining environmental quality in five Chinese cities--Beijing, Guangzhou, Shanghai, Shenyang, and Xian. One five-year analysis based on data from the Globa' Environmental Monitoring System (GEMS) established that of 170 monitored sites around the world, Shenyang, Xian, Beijing, Guangzhou, and Shanghai ranked among the 25 sites with the highest SO_2 levels. Their respective ranks were 2nd, 7th, 9th, 12th, and 21st in order of severity (see Table 2).

For a second pollutant--suspended particulate matter (SPM)--these same five Chinese cities ranked among the ten most polluted world cities, far exceeding the World Health Organization (WHO)'s minimum standard (see Table 3). Additionally, in terms of the number of days above WHO's health standards for SPM and SO_2 during a given year (1988), three of the five Chinese cities--Xian, Beijing, and Shenyang--were among the worst violators (see Table 4).

Table 2
Annu SO_2 average concentration in monitored cities, 1980-1984

Cities	Average Concentration (ug/m³)	Rank
Milan	190	1
Shenyang	180	2
Tehran	150	3
Seoul	130	4
Rio de Janeiro	120	5
Sao Paulo	90	6
Xian	85	7
Paris	80	8
Beijing	78	9
Madrid	70	10
Guangzhou	65	12
Shanghai	50	21
WHO Health Standard	**40-60**	

(Source: WHO and UNEP, 1987: 5)

Table 3
Annual SPM Average Concentration in Monitored Cities, 1980-1984

Cities	Average Concentration (ug/m^3)	Rank
Kuwait	600	1
Shenyang	420	2
Xian	410	3
New Delhi	400	4
Beijing	390	5
Calcutta	385	6
Tehran	260	7
Jakarta	250	8
Shanghai	230	9
Guangzhou	220	10
WHO Health Standard	**60-90**	

(Source: WHO and UNEP, 1987: 6)

Table 4
Average Days Per Year SO_2 and SPM Levels Exceeding WHO's Guideline (in 1988)

Cities	SO_2	SPM
New Delhi	6	294
Xian	71	273
Beijing	68	272
Calcutta	25	268
Shenyang	146	219
Tehran	104	174
Jakarta	—	173
Shanghai	16	133
Guangzhou	30	123
Bombay	3	100
Manila	24	14
Rio de Janeiro	—	11
Toronto	1	1
New York City	8	0

(Source: UNEP and WHO, 1989: 12, 29)

Chinese research on urban air quality has confirmed that the five case study cities suffer from severe air pollution. In fact, this research indicates that environmental quality has been steadily declining since at least 1980. According to China's State Environmental Protection Bureau (CSEPB), in the years between 1981 and 1985, these five cities increased their emission of SO_2 by 18 percent (CSEPB, 1985:119-124). Together, the five case study cites produced 11.0 percent of the SO_2 and 7.3 percent of the industrial dust in China during 1985.

These five case study cities illustrate China's urban environmental dilemma. China's cities have played a key role in the country's rapid growth. But development has been accompanied by significant environmental degradation. By concentrating industries within urban areas, and by relying on a coal-intensive, technologically inefficient energy system, Chinese development policy resulted in conflicts between urban life and environmental quality on the one hand, and economic growth on the other.

Industrial-based urban development

Development of China's cities as industrial centers can be historically traced. Chronic civil wars and the incompetence of the Nationalist Government had essentially brought China's economy to collapse. When the Chinese Communist Party took over the leadership of China in 1949, China's existing industrial infrastructure and skilled industrial workers were located almost entirely in its cities. Consequently, China's cities naturally bore the responsibility of national economic reconstruction. In the decades following the establishment of the People's Republic of China, continued industrial development in urban areas insured that China's cities would play an important role in the country's economic renewal. By 1985, 67 percent of China's industrial enterprises were located in cities, and the gross industrial output produced by these urban enterprises accounted for nearly 70 percent of the total output produced by the nation as a whole (CSSB, 1987: 197).

The expanding metropolises of Beijing, Guangzhou, Shanghai, Shenyang, and Xian came to dominate China's economy. As China's people and industries settled in these five cities, their influence on China's economy grew. By 1990, these five urban centers house 6 percent of China's urban population. Yet, these same five cities accounted for 9 percent of all Chinese urban industrial enterprises and produced 15 percent of China's 1990 gross industrial output. During that year, Shanghai and Beijing ranked first and second in terms of city's gross industrial output, while Guangzhou, Shenyang and Xian ranked 6th, 8th, and 26th, respectively among 467 Chinese cities (CSSB, 1991:45-54, 175-194).

The industrial enterprises located in these Chinese cities are drawn mainly from heavy industries such as iron and steel, metallurgy, machinery, petroleum, and petrochemicals. By 1990, over half of the industrial output from three of the five case study cities--Beijing, Shenyang and Xian--derived from heavy industry. In fact, several of the ten largest Chinese enterprises--among them, the Capital Iron and Steel Company, Yanshan Petrochemical Company, and Baoshan Iron and Steel Complex--are located in the case study cities. Selected indicators about the five case cities are listed in Table 5.

The significant economic contributions of heavy industries in Beijing, Guangzhou, Shanghai, Shenyang, and Xian have been fuelled by a coal-based energy system. As noted below, this system is highly inefficient and heavily polluting.

Table 5
Selected Indicators of Five Cities (1990)

Indicator	Total (467 Cities)	Beijing	Guangzhou	Shanghai	Shenyang	Xian
Population (millions)	717.2	10.4	5.9	12.8	5.7	6.0
Number of Industrial Enterprises	389,122	6,383	4,684	13,525	5,570	3,476
Industrial Output (billion RMB)	2,160.4	73.4	44.2	163.2	35.5	17.6

(Source: CSSB, 1991: 45-54, 175-194)

The problem-ridden energy system

Caught in the conventional development paradigm, the five Chinese cities in our study have consumed large amounts of energy during rapid economic growth and urban expansion. According to China's State Statistical Bureau, in 1985 these five cities alone accounted for over 14 percent of the total electricity consumed by all China's cities (CSSB, 1987:318). Electricity consumption per capita in four of these five cities far exceeded the national urban average of 113 kWh. Beijing was highest with 383 kWh per capita, followed by Guangzhou (284 kWh), Shanghai (232 kWh) and Xian (228 kWh). Only Shenyang, at 144 kWh per capita, was near the national average (CSSB, 1987:369).

Coal is the primary fuel for electrical generation in most Chinese cities, including the five case study cities. For instance, in 1988, 98.3 percent of Beijing's and 99.8 percent of Shanghai's electricity was generated by coal-burning power plants (CSSB, 1990:102-106). Additionally, due to shortages in electricity supply, many Chinese cities power their factories and households by directly burning coal. In Shanghai, for example, there were more than 10,500 industrial boilers and 0.8 million household stoves powered by coal in 1985 (Huang, 1985:756). Because of its relatively cheap price and the considerable size of national deposits, coal dominates the Chinese commercial energy sector (Table 6).

Table 6
Composition of Chinese Commercial Energy Consumption
(Percent, 1988)

Total	Coal	Oil	Hydropower	Natural Gas
100.0	76.2	17.0	4.7	2.1

(Source: CSSB, 1990: 149)

Coal is not only intensively consumed, but it continues to be inefficiently used. International comparisons of energy consumption per million U.S. dollars of Gross Domestic Product (GDP) among selected countries give strong evidence of the low level of energy efficiency in China. While industrialized countries consumed 212 to 679 tons of coal equivalent (tce) to produce $1.0 million in national output, China used nearly 3,200 tce to produce the same value of goods (see Table 7). According to Vaclav Smil, China's average fuel conversion efficiency is as low as 30 percent, compared with Japan's standard of 60 percent (1984:117). And compared with other Asian developing countries who use an average of 724 tce per $1.0 million of output (based on conversion of figures in Byrne, et al., 1992:22), it is clear that China's industrial sector is highly energy inefficient.

Table 7
International Comparisons of Energy Efficiency
(Energy consumption per one million US dollars of GDP) (tce, 1986)

China	Canada	France	Germany	Italy	Japan	U.K.	U.S.
3195	679	274	345	271	212	550	544

(Source: CSSB, 1990: 386,394)

The use of coal as a fuel source is inherently problematic from an environmental point of view. In the best of circumstances, this fuel's use can lead to major air pollution and solid waste disposal problems. Inefficient use of coal only exacerbates an already significant tendency toward environmental degradation. In China, the problem is becoming acute because more than 83 percent of the coal burned in China is not sorted or washed (Smil, 1984: 115).

The deteriorating state of China's urban environmental quality is largely traceable to the intensive and inefficient use of coal. Recently, Chinese authorities reported that 90 percent of SO_2 and 73 percent of industrial dust in its cities comes from coal-burning (Qu, 1991:83). Unless basic change is made in the energy, environment and development relations underpinning China's urban structure, urban environmental degradation is likely to continue and even worsen. The cumulative result of the country's embrace of the conventional urban development model in the form of concentrated, heavy industry-based urban structures and a supply-oriented energy system is the present condition of unsustainable development. China can no longer afford to follow its current developmental path. A policy agenda that can put China on a sustainable development path is imperative.

Policy Agenda: Toward a Sustainable Urban Future

Our analysis of the five Chinese cities points to the need for a policy agenda that will enable China to move from its current conventional development orientation toward a sustainable development path. In this section, we offer an agenda intended to begin the transition to a sustainable urban future. Three propositions guided our construction of the proposed policy agenda:

- Because China's urban environmental problems are mainly a result of national development strategy, our policy agenda focuses on national energy, environment, and development policy actions.

- China's urban environmental degradation is significantly related to the country's inefficient use of energy and, therefore, reform of China's energy system is essential.

- Finally, China's energy, environment and development choices have substantial global implications and , for this reason, cooperative international actions are needed to facilitate China's transition to a sustainable development.

Moving toward a sustainable path

China has recently been preoccupied with expanding its economic wealth, accelerating national development, and increasing production capacity. To date, this development strategy has resulted in an economic system characterized by instability, an energy system that threatens long term sustainability, and urban areas with substantial environmental problems. It is time for China to recognize the structural contradictions associated with the existing development path and embrace a policy agenda in line with the principles of sustainability.

But moving to a sustainable development model does not mean that China must surrender its recent economic success. Rather, sustainable development means redirecting the country's energy, environment and development relations so that economic growth occurs within a framework of energy conservation and environmental protection. In place of the conventional model's quantitative idea of growth, a sustainable path emphasizes economic success that is consistent with qualitative values such as improved social health and urban environmental quality. In other words, social and ecological dimensions of urban life are to be integrated with economic ones to define China's development goals. Moreover, China would seek to balance the needs and demands of its current population with those of succeeding generations under a sustainable development strategy. To meet these new goals, national policies in the areas of urban development, environment, energy and technology need to be reformulated. International support is also necessary if China is to meet the goal of sustainability.

Urban development policy

To move toward sustainable development in its urban economies, community-based rather than production-based industrial development planning becomes the mainstay of national urban policy. It is widely recognized that manufacturing enterprises, especially heavy industries, are among the largest energy consumers and the heaviest environmental polluters. Therefore, they should not be clustered within densely populated urban areas. But it must be pointed out that movement of heavy industry to outlying areas only represents a limited, short term solution to China's social and environmental conflicts. Long term solutions will require the introduction of new, more environmentally benign technologies. Further, movement toward a community orientation in industrial development planing will require greater attention to the development of tertiary industries (including professional services, information processing and trade) in cities. These industries, if developed vigorously, would ensure that China's large cities would continue as prominent centers for the national economy as well as significant cultural and political institutions.

Environmental policy

The Chinese government has tried to halt urban environmental deterioration during the past two decades. In 1978, China amended its constitution to include protection of the environment as one of society's basic commitments. Since then, China has enacted several pieces of environmental legislation and enforced a number of new environmental regulations. In addition, administrative agencies have been established at the national, provincial, and local levels. China has created a nationwide monitoring network, research institutions, and university environmental programs to address this issue. A number of localities have recently announced fines for the discharge of pollutants and begun an annual "Environmental Awareness Month." In the recent UN Conference on Environment and Development held in Rio de Janeiro, most significantly, a Chinese environmental official declared that the Chinese government has decided to bring environmental impact assessments into line with the nation's long-term development plans (People's Daily, June 6, 1992).

Although the above initiatives represent positive steps, they are not enough to solve China's urban environmental problems. Because economic growth has been considered the nation's "number one task," China's environmental sensibility has often had to give way to economic considerations. Economic measures, such as GNP, have become the dominant indicators of achievement. Environmental costs have been excluded from the cost of national economic activity, and environmental legislation and regulations have sometimes been suspended or ignored when they were seen as threatening economic growth.

But the pursuit of economic growth at the expense of the environment cannot be sustained over the long run. To address this conflict, existing methods that measure economic performance in narrow, monetary terms should be replaced by methods that include environmental realities and long-term costs. The imposition and enforcement of pollution fines, the creation of transferable emission rights, and the preparation of explicit plans to phase out certain environmentally inappropriate practices (such as burning unwashed coal) are needed. Also, annual technology and policy competitions should be held among universities, city governments and state enterprises to address urban environmental problem. In this way, Chinese society can be encouraged to develop alternatives to existing social and industrial practices that harm the urban environment.

Ultimately, if China is to halt urban environmental deterioration, it must adopt vigorous measures that seek to prevent pollution at the source. Passive cleanup after the pollutant has already been produced (the so called "end-of-pipe" remedy) is both ineffective and expensive (Commoner, 1990). Since China's urban pollution results significantly from its inefficient energy practices, a high priority for pollution prevention should be the reform of the existing energy system. Because of the unavailability of recent data, our environmental quality examinations of five Chinese cities reflect the situations of the 1980s. Since then, China has, to some extent, improved or halted the continuing degradation of its urban environmental quality. However, such improvements are limited unless China makes basic changes to its coal-based energy structure. Therefore, a structural reform of China's energy system is essential to the achievement of environmental integrity.

Energy policy

China's energy system has suffered from many problems common to developing nations pursing growth under the conventional model. These problems include: continuous shortages in energy supply, extremely low energy efficiency, a fossil fuel-based energy structure, obvious geographical disparity between energy producers and energy consumers, a concentration of energy demand within urban areas, and artificially low energy prices. These problems have led to what Amory Lovins calls the contradictory

nature of "hard path" energy regimes (1977). Their defining objective is cheap and abundant energy supplies. Yet, such systems invite waste, high levels of pollution, and a treadmill relation between energy and development. As a result, shortfalls, imbalances, and instability are logical attributes. Therefore, reform of China's energy system must begin by formulating solutions to these specific problems.

As a first step, China should begin the process of switching from an energy system that relies on non-renewable energy sources to one that relies on renewable sources. If China continues its current pattern of energy exploration and consumption, it will soon be faced with the exhaustion of its petroleum and other natural resource reserves. This will most likely occur sometime during the next century. Therefore, it is important for China to move its energy reliance on non-renewable into renewable resources. National transition to renewable resource is, however, impossible to realize overnight. Due to the country's ample and cheap coal endowment, China's energy structure will remain coal-dominated for some decades. Therefore, the new energy policy still needs to leave room for coal resources. Gradually, however, the renewable and other environmental benign resources should replace coal to become the dominant resources in China's future energy system.

China's energy transition should be guided by the objective of developing energy resources that are renewable, clean, and feasible. The highest priority should be given to solar, wind, geothermal, and biomass resources. Given China's abundance of each of these resources, the development of an energy system fueled by renewable energy is hardly far-fetched. China's geothermal resources are the world's largest and can be used for electricity supplies far beyond local needs (Smil, 1988:9, 15). Further, China has the world's largest hydro-energy reserve with a massive exploitable potential estimated at 378,000 MW, more than twice that of current national electric generation capacity (FEER, 11 June, 1992). Development of these resources should be based on their modularity and flexibility. Unlike the "hard path," what Lovins called "soft path" resources (1977) are distinctive for their ability to be scaled to community needs. This affords greater opportunities for local governance and oversight and avoids the economic and technological "brittleness" (Lovins, 1982) characteristics of large-scale, centralized energy system, such as those currently in use in China. Adoption of this approach would also enable China to avoid entanglements with such risky and costly technologies as nuclear power [for an examination of the problems of nuclear power in development, see Byrne and Hoffman (1988) and Poneman (1982)].

Besides the development of renewable resources, it is urgent that China give energy conservation and energy efficiency highest consideration in its energy planning. Resource conservation and efficiency improvements have the potential to reduce overall energy demand and at the same time to reduce environmental risks. To move toward a more energy-conserving system, the Chinese government should adopt economic, institutional, technological and planning measures that promote this resource option. The imposition of energy taxes should be considered as well as investment incentives to develop conservation opportunities as part of the country's industrial growth goals. Institutionally, national organizations responsible for promoting conservation and efficiency need to be established (see Byrne and Wang et al., 1991, for specific ideas in an Asian context).

Technologically, there are many end-use efficiency options currently available that can help China meet its energy needs as it gradually moves toward a renewable energy system. Because China is in the process of assembling its industrial infrastructure for the 21st century, this is a critical time for developing efficiency in the end use sectors--buildings, transportation, industrial process and agriculture. The country should initiate end-use efficiency planning, borrowing from the Integrated Resource Planning (IRP) model in wide use in the West. A particularly important adaptation of this model by Amulya K. N. Reddy (1985) for India should be explored. Other supply-based efficiency options of special relevance to China include increased coal-washing capacity, greater use of natural gas, and the employment of fluidized bed combustion and integrated gasification/combined cycle.

To effectively use existing energy resources, China needs to better rationalize its geographic distribution of industries. Currently, too many industries are concentrated in China's eastern and northeastern urban areas which are far from the country's renewable energy resources in the west. Therefore, a gradual shift of energy-intensive industries to the west is desirable. Such a shift will not only reduce the cost and burden of transportation of energy, but it will also contribute to an efficient and effective energy use--both of which will have a positive effect on China's urban environment.

China's centralist approach to the management of its energy system also needs to be changed. Although recent reform policies have begun to use market mechanisms to encourage decentralization, in many areas such reforms have yet to reach the energy system. First, state control over energy prices must be phased out, and energy resources must be priced in terms of their economic and environmental value. Second, governmental subsidies for energy production and consumption should be gradually ended so that energy producers and consumers bear the actual costs of energy and can adjust their practices accordingly. Third, local initiatives and participation should be encouraged in managing the energy system and its development. The current command-and-control approach to implementation should be replaced over time with market-oriented incentives and local regulation.

To technologically support the energy system's transition, China must promote research and development in renewable energy and conservation. China needs to increase its budgetary and personnel commitments in these areas. Moreover, the national government should encourage cooperation between China's industries and universities in energy research.

Seeking International Support

Since China is the world's third largest energy producer and the world's largest coal consumer, its transition to a renewable based energy system is of great importance not only to the nation itself, but to the international community as well. China contains one fifth of the world's population, therefore, its stable development is of great importance to the world as a whole. The global energy and environmental concerns recently expressed at the 1992 UN-sponsored Conference on Environment and Development in Rio de Janeiro, Brazil cannot be met if China is not an equal participant in the transition to sustainability. Therefore, the international community has a vested interest in helping China move toward a sustainable development path. Such support can come in the form of financial and technical assistance, international monitoring and technology transfer.

- The global environment fund endorsed by the developed countries at the 1992 UN Conference on Environment and Development should be implemented with specific planning to help China make the transition from its current problematic energy and environmental bases of development to sustainable ones.

- The international community can help China slow its population growth by helping to finance family planning policies and the transfer of new birth control techniques. Reduced population pressures equate to reduced energy and environmental pressures. This is of great significance for urban China because that is where half of the national population presently lives.

- China should join the international community in monitoring global environmental quality to ensure that global environmental quality targets are met.

- Because we share a "common future," as the World Commission on Environment and Development observed in its 1987 report, developed countries should be prepared to transfer their less energy-intensive and environmentally-sound "green" technologies and products to their developing partners. Also, worldwide information exchanges on new "green" technologies would be of great assistance to developing countries, including China.

Conclusion

The energy, environment and development challenges faced by newly industrializing countries like China are great. However, these challenges can be met if these countries are guided by the principles of sustainable development as described here; and if international support is mobilized to meet the needs of developing countries. Together, developing and developed countries can produce the innovative ideas and enact the policies that will make our common future a sustainable one. We owe such a future to humanity and to our natural environment.

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STATUS OF SCIENCE-TECHNOLOGY-SOCIETY EDUCATION IN THE UNITED STATES

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This study was designed to determine the number of states that are currently implementing (requiring, recommending, or encouraging) Science-Technology-Society (STS) education or its surrogates (STS-Surrogates) and to gather descriptive information about their implementation.

Operational Definitions

STS denotes the interaction (issues, concerns and problems) between science, technology and society as advocated by the STS curriculum development movement in the United States; STS-Surrogate(s) denotes those society-based, science and technology education programs which look at societal issues, concerns and problems, and do not use the term "STS" in their titles and are not directly related to the STS curriculum movement; Implementation refers to STS education in the science curricula that has been required, recommended, or encouraged by State Departments of Education. The three levels of implementation (required, recommended, and encouraged) have been chosen because implementation of educational policies varies depending upon the legislative structure of the states.

Procedure

Data from all 50 states was obtained through a telephone survey of state science supervisors during 1992. Ten states received back a random sample of their telephone survey record for validation.

Findings

According to the telephone survey, all fifty states concurred with the operational definition of STS and STS-surrogate education. Eight states made some suggestions, mostly to augment STS definition to include personal issues, and one state suggested augmenting STS-surrogate definition. In addition, the survey revealed the following picture of STS implementation in the United States.

- Eight states (AZ, FL, GA, NV, NH, NY, SC, WV) have required STS education.
- Nine states (CT, MD, MI, MN, MO, OR, TX, UT, VA) have recommended STS education.
- Twenty states (AL, AK, AR, CA, DE, HI, ID, IN, IA, KY, LA, MA, MT, NE, NJ, OH, PA, RI, TN, WY) have encouraged STS education.
- One state (NC) has required, recommended, and encouraged STS education.
- One state (MS) has required and recommended STS education.
- Six states (CO, IL, ME, VT, WA, WI) have recommend and encouraged STS education.
- Two states (NM, ND) have encouraged STS-Surrogates.
- Three states (KS, OK, SD) have neither STS nor STS-Surrogate implementation.
- Forty-five states will have some form of STS implementation by the year 1994.

- Generally, STS education is targeted for grades K-12.
- Twenty-two states have STS documentation and one state has STS-surrogate documentation.
- Twenty-five states reported that a total of 3,381 school districts (22% nationwide) have implemented STS education.
- To date, there have been (approx.) 968 inservice training/workshops conducted related to STS education.

Comments

Feedback and suggestions are sought from those who are interested in STS education in the United States to develop strategies for subsequent research: to gather and analyze STS/STS-surrogate curriculum materials and outcome studies; and to develop an implementation model for STS education.

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The Science Education for Public Understanding Program: What's New with SEPUP

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Current dissatisfaction with the results of science education programs throughout elementary and secondary schools in the United States have spawned a rebirth of interest in reforming science education (Ramsey, 1993; Yager, 1990). The calls for reform from a number of development efforts include a focus on scientific literacy and its relationship to the student's own world.

The American Association for the Advancement of Science (AAAS) identifies scientific literacy as including "being able to use scientific knowledge and ways of thinking for personal and social purposes" (AAAS, 1989:20). The choices that we make in using scientific knowledge are intricately tied to risks and benefits, social trade-offs, value judgments and compromise (Rutherford and Ahlgren, 1990).

The National Science Teachers Association Project on Scope, Sequence and Coordination of Secondary Science (SS&C) has a focus on greater depth of science understanding and less coverage, with appropriate sequencing matched to the developmental levels of students. The SS&C approach is to provide some science in the four areas of biology, chemistry, physics and earth/space science each year in grades 7-12 to every student (Aldridge, 1992). SS&C has several state projects (Alaska, Iowa) organized around the relationship of science and scientific literacy to real-world problems.

Issue-Oriented Science

The approach of the Science Education for Public Understanding Program (SEPUP), headquartered at the Lawrence Hall of Science in Berkeley, is to promote scientific literacy by teaching students about:

- Evidence-based decision making
- The nature of science: Experiments and evidence
- The limitations of science: Uncertainty and controversy
- Thresholds, toxicity and risk
- Living with chemicals
- Science and social systems

SEPUP does not teach students what decisions to make. Instead, the program provides the necessary knowledge and understanding so students can more effectively make *their own* decisions as members of a free and democratic society (SEPUP, 1993).

Currently, there are 12 published modules which focus on chemicals in the real world, and evidence-based decision making for middle and high school students. These are referred to as the CEPUP modules, reflecting the original program name (Chemical Education for Public Understanding Program) and the focus of our development efforts from 1987-1992. Each CEPUP module, consisting of six to eight activities, normally requires in the range of 10-20 class periods for completion.

With a new grant from the National Science Foundation, SEPUP is currently developing two year-long courses for the early secondary grades (7-10) which will feature an integrated approach to teaching issue-oriented science. The SEPUP courses, which will continue the activity-based approach of the CEPUP modules, will be interdisciplinary efforts to make the concepts and techniques of the physical, earth and life sciences relevant to the experiences and environments of the students.

Thirteen SEPUP Program Development Centers (PDCs) have been selected to field-test the first of the two courses during the 1993-94 school year. These PDCs include schools and/or multiple school districts in Alaska, New York (2 centers), California (2 centers), Kentucky, Louisiana, Oklahoma, Michigan, North Carolina, Pennsylvania, Colorado, and Washington, DC. A broad range of student abilities and community environments are represented among the PDCs, from core inner city schools to suburban and rural schools. The SEPUP Centers are the critical quality control component in our development efforts.

Course One: A Capstone Course for M/JH

The first SEPUP course, designed for students in grades 8 or 9, will focus on concrete and experience-based issues that impact either on students' own lives or their local communities. A large component of this course will be adapted from existing CEPUP modules, including *Chemical Survey, Solutions and Pollution, Risk Comparison, Determining Threshold Limits, Chemicals in Foods--Additives, Investigating Groundwater--The Fruitvale Story, Toxic Waste--A Teaching Simulation* and *Plastics in Our Lives.*

The course will be integrated to develop thematic connections to enhance student learning. Activities which encourage students to interrelate their learning from several units, and to gradually become more independent in the design, analysis and reporting of lab experiences, will be featured. In the beginning of the course, issues of water quality and distribution will be one content focus. To enhance student problem-solving skills, we will include material on chemical and biological risks, resolving issues, studying thresholds, toxicity and dose, and investigating ground water and hazardous materials. A structured student project will be built into the second semester of the course to incorporate local community issues, policy components and possible actions.

Course Two: Science for Citizenship in the 21st Century

The second course, targeted for grade 10, will include more abstract issues, including those with global implications and more difficult trade-offs. Sustainable development, the international U.N.-sponsored goal for environmentally responsible development, will be a major theme. Most of the materials for this course will be developed during 1994 and 1995. Topics under consideration include comparing environmental health risks, biotechnology, global implications of energy sources and global atmospheric changes.

Assessment

SEPUP course development and assessment development is proceeding together in a highly interactive mode. We want to be able to assess important cognitive variables and objectives, such as societal decision-making, evidence acquisition, conceptual tools, and communication skills. In addition, attitudinal domain areas such as interest in science, the importance of science to everyday life and for careers, and enjoyment of science are important SEPUP outcomes.

In developing the two courses, and training the field-test teachers, SEPUP will emphasize the close relationship between assessment and learning. In developing the assessment tools for the first course, a variety of assessment modes will be employed.

- Paper and pencil tests, the "norm" for most science programs, will be adapted to include a wider variety of item types. Formative and summative tests will stress higher cognitive and affective understandings and applications.

- Performance-based tasks will enable students to demonstrate what they know about science, how they apply what they know, and how well they can explain, articulate and defend what they have done and its implications.

- SEPUP Journals will be a central feature of the course. The student journals will organize and document the full range of an individual student's work in and out of class. Journals will encourage student reflection, as well as help us to gain insights in students' understandings of course concepts and activities. The Journals will reinforce the importance of written communication skills.

- Student-teacher interactions will be employed to provide opportunities for focused discussions between individual students and the teacher. Conducted at critical junctures in the unit or course, these interviews will provide feedback on student perceptions, understandings, problems, etc.

Conclusion

This brief summary of the current development directions of the two, year-long courses in the SEPUP program illustrates the importance we place on teaching science through evidence-based decision making.

Students must learn how to ask pertinent questions, obtain evidence and use it in reaching decisions. Students need to understand the limitations associated with scientific evidence. They must understand the nature of scientific inquiry to be able to participate in making effective science-related policies (Thier, 1989).

If the SEPUP courses demonstrate progress toward achieving these objectives, SEPUP will have made a significant contribution to the current science education reform movement in the United States.

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SCIENCE AND LITERATURE: LINKING AND LOVING THEM
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Many teachers are uncomfortable and fearful about teaching science, even at the early childhood and elementary levels. One vehicle which is helping to lessen the discomfort and fear is the use of literature as a means of teaching science content. Trade books help both teachers and children to see science as part of everyday life. These books help science become more meaningful and understandable, which helps to improve the attitude and interest of both teachers and children about science.

KEY POINTS ABOUT TEACHING SCIENCE

1. Science is part of a child's daily life. Make use of daily life events and interests as teaching tools.

2. Children learn best by DOING. Give every child a chance to be part of the activities.

3. Make each experience as non-threatening as possible. Many children become science-phobic at an early age.

4. Create an atmosphere that encourages creativity and discovery within a safe, secure environment.

5. The teacher's role includes providing time and materials for exploration, while also helping to clarify and expand on concepts.

6. Give children ample time and opportunity to think, ask, and answer questions. Encourage divergent thinking.

7. Remember that a teacher's enthusiasm (or lack of it) is contagious.

8. Strive to teach both the processes and content of science.

9. Encourage students to view "failures" as learning experiences. You need to model this attitude!

LINKING LITERATURE AND SCIENCE

Children's literature can be used to heighten children's interest in science while also introducing facts and concepts. (Dole & Johnson, 1981; Guerra & Payne, 1981).

While the stories themselves are a great motivating force, the children come to a better understanding of the use and value of science in everyday life.

Children tend to be more successful at learning if they find meaning in the content to be learned.

CRITERIA TO CONSIDER IN CHOOSING LITERATURE TO LINK WITH SCIENCE

Identify science concepts you would like to use in the integration process.

Search for stories that deal with these concepts.

Content should be accurate for science instruction.

Topics should fit the curricular needs and the interests of the children.

Check for age-appropriate format, readability, vocabulary, and content.

Make use of the expertise of school and local librarians that specialize in children's literature.

SAMPLE SELECTIONS AND ACTIVITIES

STORY: The Magic School Bus Inside the Earth, by Joanna Cole.

MAJOR SCIENCE IDEAS:

There are 3 layers of the earth: crust, mantle, and core.

The crust consists of different types of layering of soil and rocks.

Geologists are scientists who study rocks and the earth.

Sampling is one technique utilized by geologists.

SUGGESTED ACTIVITIES:

Make cupcakes with different colored layers. Using a small piece of a straw have children remove samples from the cupcakes and OBSERVE the sample once it is removed from the straw. (Blowing the sample out is lots of fun!)

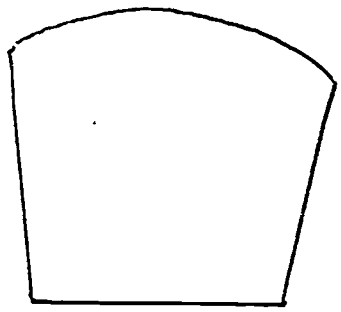
Older children can draw pictures of the sample to RECORD DATA. Have children compare and contrast samples. (See Figure 1).

Explain that sampling is done by geologists when they study the earth's crust. One of the things they've learned is that the crust of the earth is formed in layers, just as these cupcakes have layers.

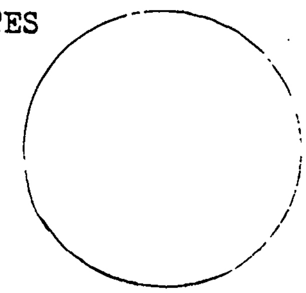
Figure 1

CUPCAKE GEOLOGY
DATA COLLECTION SHEET

HYPOTHESIS #1



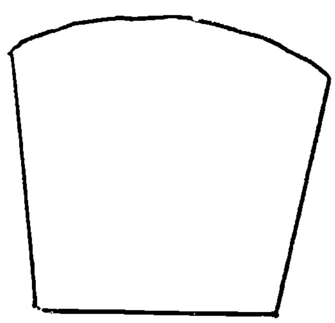
SAMPLE SITES



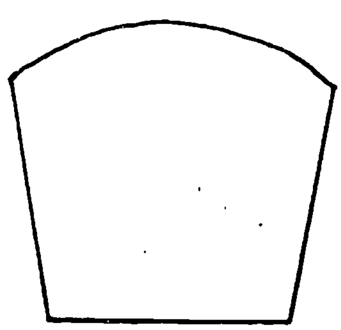
DRAW AND DESCRIBE IN WORDS EACH OF THE SAMPLES THAT YOU COLLECT.

<u>SAMPLE 1</u> <u>SAMPLE 2</u> <u>SAMPLE 3</u> <u>SAMPLE 4</u>

REVISED HYPOTHESIS



CROSS-SECTION DRAWING OF ACTUAL SAMPLE "CRUST".



Read The Magic School Bus Inside the Earth once the major concept of layering has been discovered. The children are sure to enjoy the field trip deep inside the layers of the earth with Ms. Fizzle and her science class.

Show examples of photographs and real samples of rocks or ground samples that contain layered formations.

OTHER BOOKS:

Inside: Seeing Beneath t'.e Surface by Jan Adkins has some excellent examples of cross-sectional drawings that can be used with this activity.

STORY: Sylvester and the Magic Pebble, by William Steig.

MAJOR SCIENCE IDEAS:

Classification is the process of putting like things together.

This lesson also provides practice in observing and describing.

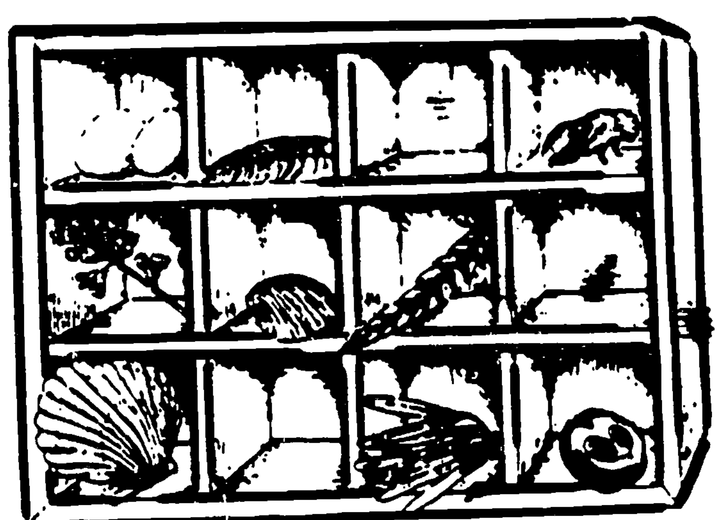
SUGGESTED ACTIVITIES:

Read the story Sylvester and the Magic Pebble.

Sylvester had a wonderful collection of pebbles. In order to develop the process skill of CLASSIFYING, have children gather samples of some type of matter to form a collection.

Suggested materials:
rocks
feathers
seeds
shells
insects
leaves

Using small milk cartons, children can form a "minimuseum" of their collections. Older children can use labels to identify each item in the collection.



"Minimuseum"

BEST COPY AVAILABLE

Further OBSERVATION and discussion can follow.

Possible questions:

How are these objects alike? How are they different?

Why did you group these objects together?

What is special about the objects in your "minimuseum"?

OTHER BOOKS:

Everybody Needs A Rock , by Byrd Baylor, is a story that has some great guidelines for gathering collections.

Tana Hoban's book, More Than One, has some beautiful photographs of collections of things.

Josephina - The Great Collector by Diana Engel will add some humor to the challenges of being a "collector".

STORY: The Troll Music by Anita Lobel.

MAJOR SCIENCE IDEAS:

Sounds are made from vibrations.

The vibrations in different materials will make different sounds.

SUGGESTED ACTIVITIES:

Read the story, The Troll Music.

Provide time and materials for children to make their own instruments.

Simple kazoos can be made by using toilet tissue cardboard rolls. Make a small hole (about the size of a pencil pushed through) about 2 cm from the edge of either end of the tube. Cover the opposite end with a small square of wax paper and secure the paper with a rubber band. By simply blowing and/or humming through the open end of the tube the vibrations will produce some interesting sounds.

Pop bottle bands can be made by filling soda pop bottles with different amounts of water. The bottles can be tapped to produce sound, or sounds can be produced by blowing across the top of the bottles. Have children experiment with the sounds.

Rubber band instruments can be made by wrapping rubber bands around small cardboard boxes. Try different sized boxes and rubber bands to experience different sounds.

with respect to real things or technology in the form of tools, instruments, machines, processes and materials. It is the principle of the application of knowledge in relation to real and tangible items where science and mathematics become realistic and achieve a dimension of concreteness.

As technology education's transition from industrial arts education continues to be defined, it is apparent the study of technology cannot be accomplished within a single discipline. Maley (1987), Zuga (1988), Savage and Sterry (1990), and Loepp (1992) are among the noted technology educators who have recommended an interdisciplinary approach for teaching technology education content. The very nature of technology in its evolution, utilization, and significance cuts across the boundaries of all disciplines. With this in mind, technology education teachers must not remain isolated from other disciplines; rather they should provide the impetus for integrating curriculum within their schools. The uniqueness of the technology education laboratory provides students with the opportunity to become involved in manipulative activities, problem solving, experimentation, design, and correlation with other disciplines. These elements are consistent with the needs addressed by mathematics and science advocates. Science and mathematics education practitioners have recognized the importance of experiential activities as a means of providing an application for mathematics and science concepts. The American Association for the Advancement of Science (AAAS) in its report, Science for All Americans (1989), recommended that science teachers stress ideas and thinking rather than the memorization of isolated facts. Hands-on experiences were encouraged as a means of presenting the applications of science principles in a meaningful manner. The AAAS report urged that science should not be taught as a separate discipline. Increased integration of math, science, and technology was suggested.

The release of the National Council of Teachers of Mathematics (NCTM) report titled, Curriculum and Evaluation Standards for School Mathematics (1989) provided a response to the need for change in the way mathematics is taught. Among the recommendations offered by the NCTM is that students learn math by doing purposeful activities that require manipulative experiences. NCTM proposes that students be exposed to the use of math and science as they relate to other fields. Teachers are encouraged to engage their students in meaningful problem solving to enhance the learner's mathematics knowledge.

Members of the International Technology Education Association (ITEA) have developed a number of exciting programs for mathematics, science, and technology education integration. These programs have provided educators with the opportunity to make the study of technology central to the application of theories, principles, and concepts found in math and science. Activities supporting each program can be facilitated primarily in the technology education laboratory. This point is definitive: the work students perform in the technology education laboratory is intrinsically related to the principles of science and mathematics. It is apparent the technology education curriculum can strengthen its position in the school by providing the catalyst by which math, science, and technology education can be integrated, thus meeting the demands

for integration each area advocates. The benefits of such an integration to the technology education program are numerous. The most obvious advantage is that students integrate their knowledge in an educational format. Second, the technology laboratory becomes an area for coordinated efforts to provide holistic learning. Another result is the increased stature of technology education programs in the schools. Coordination takes place between the three subject areas, which until recently have remained compartmentalized. The integration process allows teachers who are threatened or "turf oriented" to develop an appreciation and understanding of the role each discipline plays in the educational process. Cooperation may be achieved when the common goal is perceived by all: the preparation of our students for life in a technologically advanced society. Students will have a place where they can apply what they learn in other disciplines when they participate in technology education activities. The type of first-hand experiences provided in the technology education laboratory exposes the student to real-life situations and the relevance of what is taught in other classes.

Collaboration among the disciplines may happen naturally. It may occur due to an outside impetus as was the case in Indiana.

The Workshop

The Department of Industry and Technology, Ball State University, hosted its first Workshop for the Integration of Mathematics and Science Within Technology Education during the summer of 1992. The two-week workshop was devoted to establishing a cooperative effort between mathematics, science, and technology education teachers. Among the goals established for this project was to provide an atmosphere that emphasized the important role technology education plays in the school. An effective study of technology should include mathematics and science literacy. Technology education uses methodologies and instructional strategies that blend the principles of math and science into the study of technology, resulting in improved understanding of technology by the student.

Fifteen Indiana middle and high school teachers, representing the school corporations of Alexandria, Anderson, Centerville, Yorktown, Portage, Marion, and Muncie, participated in the workshop. Each school sent a team with a representative from technology education, math, and science. This strategy was adopted in order to achieve understanding, as well as cooperation, among the individual members of the teams during the program. Further, the teachers came from the same school so interaction and cooperation could be continued in the home school after the project was completed. Teachers were recruited for the project on the basis of recommendations from supervisors, telephone calls made by the project director, and announcements of the project at several meetings of Indiana education organizations. On April 25, teachers were invited to request a place in the workshop. A June 7th deadline was deemed reasonable for a response. The teaching teams were selected on a first-come, first-served basis. Participation was voluntary. Teachers from middle school and high school were invited to participate. The primary groups targeted were from technology education, mathematics and science. The workshop was used as a mechanism to

encourage teachers from the three subject areas to work together to promote cooperation among technology, math and science.

The Workshop for the Integration of Math and Science Within Technology Education was designed to emphasize a holistic form of education where each discipline contributed to a more complete understanding of technology. The goals of the Workshop for the Integration of Math and Science Within Technology Education were to:

1. create an increased understanding and cooperative relationships within the school, especially among mathematics, science, and technology education.

2. establish a framework for technology education as an important component within a holistic education.

3. provide all students with the opportunity to participate in realistic educational experiences with regard to an interface of mathematics, science, and technology.

4. develop instructional materials which allow the process of integrating math, science, and technology to occur in a natural manner.

5. provide impetus for the further integration of subject matter in the school.

Teachers attended the workshop for eight hours per day. The daily routine of the workshop included an early morning information session. During the first week of the program, Dr. Donald Maley, Professor Emeritus, University of Maryland, College Park, presented a number of lectures dealing with the importance of technology education to the school curriculum, as well as special topics on the interface of math, science, and technology education. Mrs. Mary Dollison, founder of the Motivate Our Minds (M.O.M.) project of Muncie, Indiana, was invited to speak on at-risk students, underrepresented populations, and minorities during the second week of the workshop. When these sessions were over the teachers went to work. The first few days were spent brainstorming and identifying content and principles that were taught in the technology education class. The work sessions continued through the afternoon. The last hour of each day was spent in a show-and-tell period. This time was an essential and valuable part of the program. It allowed the work of each group to be validated by the workshop participants. There was always an exchange of ideas and suggestions for the improvement of the curriculum materials. This critique of information allowed the teams to develop cutting edge materials. A significant aspect of the ten day workshop was that it provided a forum for practical applications of mathematics and science within technology education activities. The curriculum materials developed were appropriate for the three areas.

The role that each teacher played was important to the success of the group. Each team was expected to develop a minimum of five instructional units. These

units included an overhead transparency, a mathematics information sheet, and a science information sheet. It was the responsibility of the technology education teacher to identify the specific technology topics to which the math and science concepts were interfaced. The technology teacher produced an overhead transparency which included math formulae and science principles provided by the math and science teacher. The math and science teachers were charged with describing and identifying math and science concepts or applications associated with the technology education content. The math and science teachers prepared the information sheets for their respective subjects. Once these materials were formatted and approved they became the units of instruction for the integration of math and science within technology education. The final editing and formatting was carried out with the help of three project assistants, Mike Evans, Kelli Vanosdol, and Jim Diebley. Charles Ridgeway was the graphic artist who assisted the teachers with the development of the transparency masters and computer designs. At the end of the workshop each teacher was provided with a copy of all of the instructional units developed in the workshop. The document contained thirty units of instruction. An example of one unit can be seen in Appendix A.

Program History

The first Integration of Math and Science with Technology Education workshops were developed by Dr. Donald Maley, Professor Emeritus, at the University of Maryland, College Park, in 1984. The program evolved from graduate course work which was designed by Maley to improve teaching methodologies in technology education. Among the topics presented by Dr. Maley was the importance of understanding the relationship between mathematics, science, and technology. A group of fourteen graduate students, which included the author, was charged with the task of developing instructional materials which integrated math and science into technology education. At the end of the semester, fourteen instructional units were developed by Maley's class.

Maley was encouraged by other technology education specialists to bring this methodology to teachers in the state of Maryland. A series of state-wide conferences dealing with the Integration of Math and Science into Industrial Arts/Technology Education was implemented in the spring of 1985. It was during these conferences that supervisors and curriculum specialists were introduced to this unique approach to teaching technology education. The Division of Vocational-Technical Education (DVTE) of the Maryland State Department of Education readily endorsed Maley's program. In the summer of 1985, the Department of Industrial Technological and Occupational Education of the University of Maryland, College Park, jointly sponsored the first Integration of Mathematics and Science Into Industrial Arts/Technology Education.

The two-week workshop was attended by teachers who were selected on a volunteer basis. Teaching teams were comprised of one math teacher, one science teacher and one technology education teacher. The teaching teams prepared five instructional units which included a transparency master, description sheet of the technology to be studied, a math concept sheet and a

science principle sheet. These were later assembled into a volume which was distributed to the participants.

The workshop became an extremely popular program within the state. The Integration of Math and Science Into Industrial Arts/Technology Education was funded by the DTVE for three years, from 1985 through 1987. After a one-year hiatus, the project was transferred to the University of Maryland, Eastern Shore. The project received national attention from an article published in the Technology Teacher, the professional journal of the ITEA. To the credit of Maley and the program, three of the participating technology education teachers were recognized in 1985, 1986, and 1987 as Maryland's Technology Teacher of the Year by the Technology Education Association of Maryland (TEAM) and the International Technology Education Association (ITEA).

The author assisted and coordinated the program with Dr. Maley during the first three workshops. The 1989 workshop was coordinated by the author. Arrangements for the Eastern Shore project were made by Dr. Leon Copeland.

Participant Reaction

The reactions to the Ball State University project were very encouraging. A number of the participants described the activities as being beneficial to their teaching. Many of the participants declared a new respect for their colleagues' efforts. The workshop provided many of the teachers the opportunity to see and evaluate lessons and content that was being disseminated in their own schools for the first time.

All were unanimous in their agreement that the validation process (show and tell) was done in a non-threatening atmosphere. Several of the teachers indicated they were hesitant to present materials in front of colleagues, but as the week progressed they came to enjoy the daily ritual because of its positive reinforcement.

One observation was that not only had each team become an effective working group, but the fifteen participants became a very tight unit. Often team members from the various schools would collaborate when a concept was unclear. The camaraderie which developed over the two weeks was very apparent. Several of the participants commented that they planned to communicate and if possible work with their new friends from other schools.

More important, however, was the new found sense of purpose many of the teachers stated they acquired from the workshop. They were encouraged to know there were others in the school willing and able to assist in the development of meaningful lessons and activities.

An unexpected benefit that was noted on many of the evaluation surveys was the reference to the computer facilities. The teachers learned to use the Macintosh computer and a variety of software programs. The teachers commented that they appreciated the chance to receive training and have opportunity to use the computers and software.

Two of the major outcomes from this program were:

1. The technology teachers developed insight into the relevance of mathematics and science in what they were teaching.

2. The mathematics and science teachers found new applications for their content in what was taught in technology education.

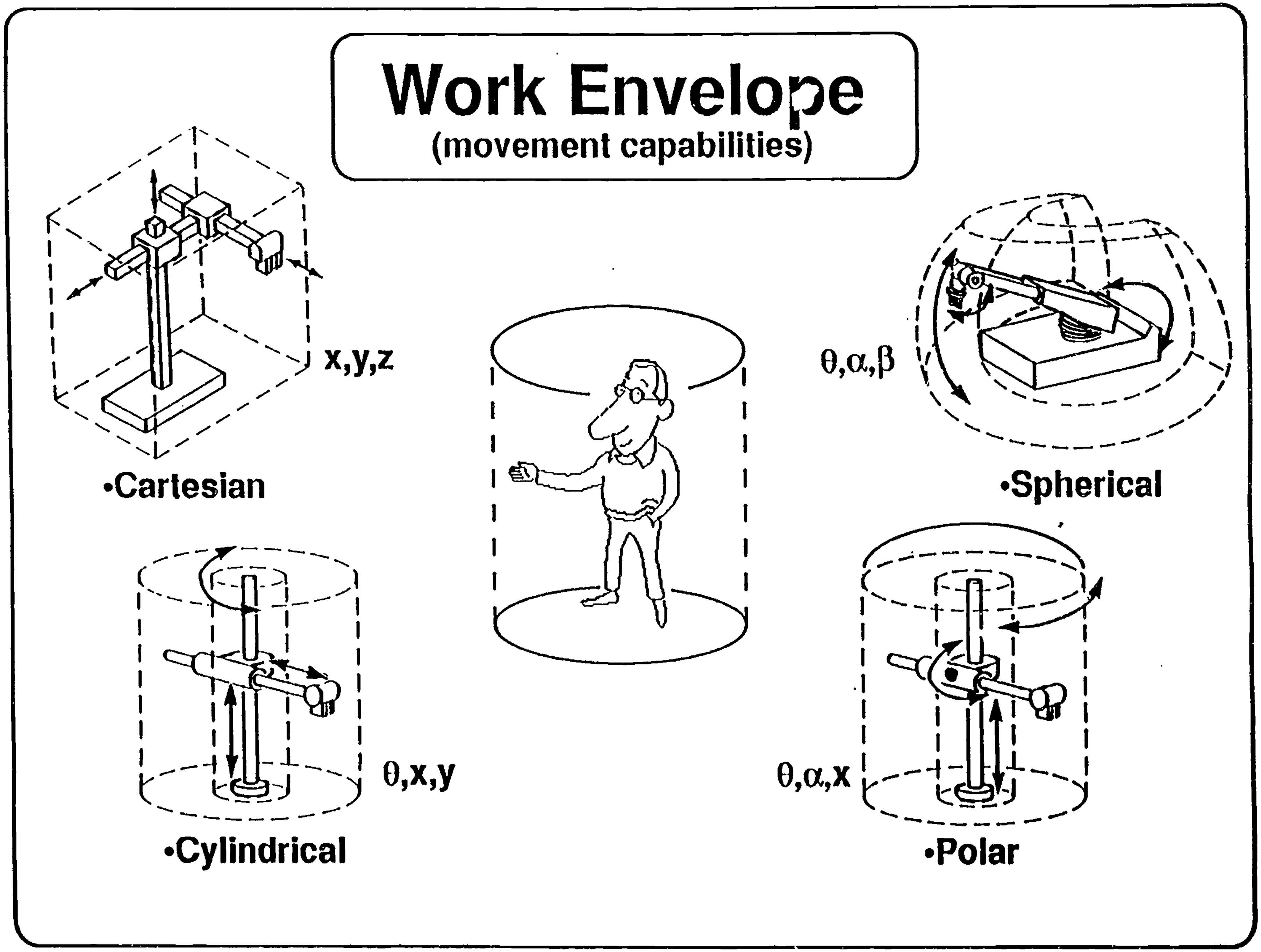
Classroom Applications

It was anticipated that participation in the workshop could stimulate further integration of math, science, and technology education by the teachers involved. The teachers who were unable to attend the workshop can share in the knowledge by accessing the document containing the integration units produced by the first group of teachers involved with the project. It is hoped the publication will inspire them to attempt an interface between mathematics, science, and technology education.

The publication may be used in a number of ways. It may be employed as a reference for specific technology education topics that are taught in the classroom. The integration units may be used to enhance technology education lessons which are currently taught without a math and science interface. The units represent the content which is taught in the technology education classrooms of the teachers who produced these materials. The work may be modified to suit any program. A special effort was made to develop overhead transparencies which incorporated general concepts which later, through a number of transparencies, detailed a specific topic within the realm of technology education. The depth and breadth of study depends on the individual teacher.

The materials generated in the workshop represent a successful integration of math, science and technology education. There is the expectation that the document containing the integration units will be used as a model for future integration of all subjects within the school. Although this workshop was aimed at enriching the content of technology education, it is hoped that other professionals recognize the value of integration of all subject matter as a means of providing a holistic and relevant education.

The usefulness of the workshop and the integration document as an impetus for integration of subject matter depends on cooperation and communication among professional educators. This will require a subtle change in attitudes toward colleagues and their subject matter.



Appendix A

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Title: Robots

Category: Innovation

Description:
Robotic technology refers to the design and application of robots, and specifically of industrial robots that are used for manufacturing or construction with the purpose of handling, processing, assembly, and inspection of materials and parts.

Science Concepts:

1. **Damping**—when an oscillating object decreases its amplitude over a period of time. Air resistance and internal friction cause the energy of motion (kinetic energy) to transform thermal energy (heat) and decrease the amplitude (measure of potential energy).
2. **Electronics**—branch of physics that is concerned with the emission, behavior, and effects of electrons in devices and the utilization of the devices. Semiconductors and transistors are essential components of modern electronic devices.
3. **Friction**—a force that acts in the opposite direction to the direction of motion of an object caused by the adhesive force of the atoms of the object and the atoms of the surface.
4. **Hydraulics**—the use of fluids to transmit pressure.
5. **Mechanics**—a branch of physics that is the study of the motion of large objects using Newton's Laws of Motion. (The study of motion at the atomic level is Quantum Mechanics.)
6. **Moment of Inertia**—a body in circular motion tends to stay in motion (Newton's First Law) with an angular acceleration proportional to the torque applied to it.
7. **Pascal's Principle**—states that the pressure applied to a confined fluid increases the pressure throughout the fluid by the same amount.
8. **Pneumatics**—the use of a gas (or compressed air) as the "fluid" to transmit pressure.

Science Relationships:

1. Each movable robot limb is fitted with a device that produces an electronic signal which is proportional to the limb position. The system is arranged to minimize positional error by oscillation (use of damping).
2. Friction forces are used to clamp (or grip) and hold objects manipulated by a robot.
3. If the center of gravity of the object being moved by the robot is outside the line between the two jaws, a moment (torque) due to acceleration forces will tend to pivot the part.
4. Pneumatic systems have enough torque to lift 6.5 to 10 lbs, electric drive systems can lift 6.6 lbs to 165 lbs, while hydraulic systems are capable of of lifting 50 to 300 lbs.
5. The work envelope of a robot is the three dimensional area in which the robot can move. A Cartesian coordinate robot has a rectangular-shaped work envelope, the cylindrical coordinate robot has a cylindrical work envelope, the polar coordinate robot has a spherical work envelope, the revolute (or articulate) coordinate robot has a tear-shaped work envelope.

Math Concepts:

Coordinate Systems:
Cartesian—three linear axes measures
Cylindrical—one angular measure and two linear axes measures
Polar—two angular measures and one linear axis measure
Revolute—three angular measures

Computer Programing (Orientation) Skills (telling the robot to do what you want it to do). Some languages that companies may include: Basic, Cobol, Fortran, Pascal, Logo, or Forth.

Cosine Law: $c^2 = a^2 + b^2 - 2ab \cos C$

Force (clamping) F m = weight X (2) if moved horizontally
F m = weight X (3) if lifted vertically where m is the coefficient of friction
Example: Find the force a robot must exert to lift a weight of 25 pounds vertically, if the coefficient of friction is .15 and a reasonable safety factor is 2.
$F \times 0.15 = 25 \times 3$
$F = 500$ lbs
With a safety factor of 2 , the gripping force is 1,000 lbs!
Geometry
Angle measurement, 0° through 360°

Complementary Angles—Two angles whose sum = 90°
Figures (cylinders, spheres, planes, lines, circles)
Formulas:

$C = 2\,p\,r$ Circumference = 2 X 3.14 X radius of circle

$l = \frac{m}{360^{\circ}} \times 2\,p\,r$ arc length = central angle X circumference ÷ 360°

Locus of Points—A geometric figure containing the set of all points that satisfy a given condition, or a set of conditions.

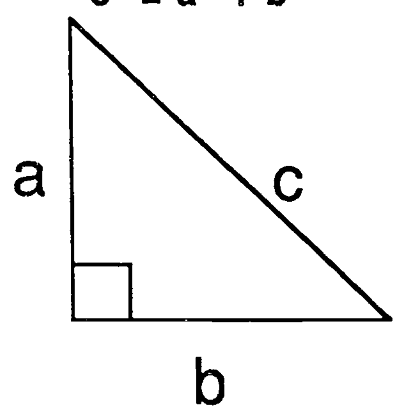
Similar Triangles—Corresponding sides are in proportion and corresponding angles are congruent (have equal measure).

Pressure = r g h where r is the density of the fluid, g is the acceleration of gravity, and h is the height of the liquid to the surface from the point where the pressure is being measured.

Problem Solving—Analysis, Heuristics, Spatial visualizations ("seeing" the problem, and the solution)

Pythagorean Theorem—In a right triangle, the square of the hypotenuse (longest side) is equal to the sum of the squares of the other two legs .

$$c^2 = a^2 + b^2$$



Ratio & Proportions— If $\frac{a}{b} = \frac{c}{d}$, then ad=bc

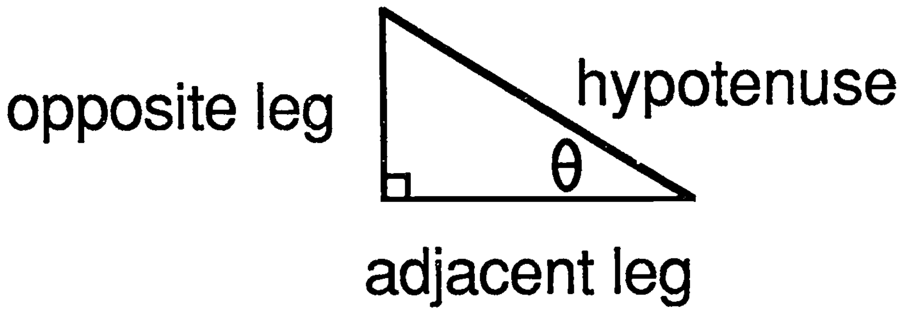
Real Numbers—Decimal and fractional forms.

Slope Ratio = $\frac{\text{Difference in the x coordinates (rise)}}{\text{Difference of the y coordinates (run)}}$

Torque, t = r F where r is the radius if the motion is circular, and F is the force applied perpendicularly to the radius. OR

$t = m\,r^2\,a$ where m is the mass of the object in circular motion, r is the radius of the circular motion, and a is the angular acceleration rate

Trigonometry Ratios—In all right triangles .....



$\sin q = \frac{\text{opposite leg}}{\text{hypotenuse}}$ $\cos q = \frac{\text{adjacent leg}}{\text{hypotenuse}}$ $\tan q = \frac{\text{opposite leg}}{\text{adjacent leg}}$

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STS: A COST EFFECTIVE CLASSROOM ALTERNATIVE TO "PULL OUT" SPECIAL EDUCATION PROGRAMS

ORLY MUNZING
NEWFANE ELEMENTARY SCHOOL
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The subject of my presentation is "STS: The Cost-Effective Classroom Alternative to 'Pull Out' Programs". I will address the following topics :

* a philosophy about special children and learning
* some achievements from my school, where the STS model is used with special children in the mainstreamed classroom
* the cost-effectiveness of the STS model
* some personal perspective on the philosophical, political and economic factors involved in utilizing STS programs in the mainstreamed classroom.

I am a learning specialist, a special education teacher from the Newfane Elementary School in Newfane, Vermont. I believe that children have not only the right to learn, but also the right to individual dignity and respect. Carl Sandburg said, "There is only one child in all the world and the name of that child is all children".

The teacher 's reason for being is to develop the potential in children through the teaching-learning process. As learning is the primary goal and value of education, then why does respect for learners in schools appear to be eroding? There are several reasons for this, but one is the tendency to set aside children who do not respond to traditional education. A common approach for special education children is to pull them from the mainstream classroom. Needless to say, this greatly increases costs, a political problem in an era of ever decreasing resources.

We must make a deliberate effort to stop such devaluation of human worth and confirm our belief that all children have an equal right to learn. I am specifically concerned about children who, for a variety of reasons, have language learning problems and are blocked from learning through traditional instructional procedures. These children can learn, but they learn differently.

All teachers see such students daily. Special students may have difficulty in expressing themselves in oral and written language, despite good cognitive abilities. Special students frequently do not acquire oral and written language skills through modeling and traditional instruction. These students seem to learn best from an approach which utilizes their cognitive abilities rather than rote memory. They come from all backgrounds, many that are warm, stable and enriching, yet many special students fail to achieve in our language-oriented education system. Their self-esteem deteriorates into disappointment, sadness, anger and depression. For too long, we have failed these students by neglecting to develop effective alternative programs.

I was one of those special education teachers who, like most, would pull special students from the classroom and bring them to the school's resource room, in the belief that isolation from the faster paced classroom would be more conducive to learning. When it came to science instruction, I only knew how to follow a textbook, from which I would present information and ask questions to which I knew the answers. My students learned to answer what I wanted to hear, though I knew that they were not truly inspired. Accordingly, I was terrified of teaching science. I also questioned whether the resource room improved the quality of education for my students. To top it all, I was frustrated with the time lost in travel, off-task activities and greeting students, all of which cut into my instruction.

I began searching for a different method. When I came across the constructivist philosophy I became excited again. My eyes opened to the "developmental approach" of producing thinkers who are creative and critical. I tried using the constructivist approach in the resource room and repeatedly observed that a hands-on way of presenting and receiving information allowed the children to internalize and to express their new-found knowledge in joyous ways.

Soon thereafter I discovered STS and began to apply it in my resource room. As I anticipated, STS is successful with special students. Since multi-sensory activities are encouraged, it compensates for their memory and/or perceptual problems and allows them to learn through experiencing the instruction as much as by hearing or seeing it.

With STS, a methodology of thinking is taught, of how to conceptualize or group ideas in a logical systematic manner. A principal purpose is to integrate different concepts. There is fulfillment of the need of the student to know why he or she is learning. As a r ılt, students who participate in STS activities have a personal investment in the process. It is easier for the teacher to teach a concept and for the student to generalize it. Thus, the teacher does not need to reteach as much later on.

STS lessons begin with a broad category. This allows the student to enter with a correct baseline (or prior knowledge), which must occur before any new learning. A goal of the teacher is to maintain the same objectives as narrower concepts are taught within the broad category. This obligates a teacher to begin each lesson by identifying both the category and each student's baseline. For both the teacher and the students, this is critical for effective lesson planning.

STS provides the student with "deep learning". It allows many opportunities to generalize information, i.e., to transfer it from one area to another. The student acquires the ability to make decisions and to discriminate between concepts. Moreover, STS is a program that allows for the different learning capabilities of individuals. Attention is given both to inductive and non-inductive learners.

One day, as I was working in the resource room using constructivist methods with the low level group of our third grade, the children expressed the view that it would be more fun to have the entire class share in what they were doing.

I presented this constructivist idea to the whole primary unit consisting of first, second, and third grade teachers. They thought the idea to be wonderful, and together we agreed to participate in the first annual Vermont Chautauqua Program of STS teacher training. The program was designed to stimulate improvements in science teaching in grades K through 12 in the State of Vermont.

We came back feeling we had good tools to meet the diverse needs of all students in the natural environment of the classroom. Together we presented the STS method to the principal, who agreed to let us test it. There were immediate changes in my role as the learning specialist and in the tasks of the four special education assistants in my school. We now work in the classroom with the classroom teachers. As a result, there is an increase in the number of individuals who can provide cues and assistance to the students. All students, whether considered disabled or nondisabled, are now provided educational programs geared to their unique interests, need and capabilities, and challenged to be the best they can be. The end result is that more children are served, including kids who fall through the cracks of a special education eligibility formula.

At the Newfane Elementary School, we use teaching strategies that effectively adapt to the curricula needs of all students, disabled or not. A key component to our successful STS program is the use of Robert Slavin's "Jigsaw Cooperative Learning Program," through which each student

is responsible for learning and teaching a unique part of the lesson. A student can achieve his or her goal regardless of whether or not similar goals are achieved by others. With this method it is important to keep the group small limited to two or three, and to assign an important but manageable role to the difficult student. One technique is to broaden the group goal so that special students must be included and, if needed, to formulate group rewards that are especially attractive to them.

It is important to avoid frightening off better students through fear that grades will be lowered by the presence of the difficult student. We found that it is effective to use individual testing for important work. Another technique is to monitor, but avoid intervention unless absolutely necessary. We process the lesson with care, sometimes joining into an activity of the group with the difficult student.

It is very useful to assign special roles to students who are not easy to include in cooperative relationships. For example, the student who is shy or needs to learn how to ask questions and listen carefully to others might be assigned the role of lesson "recorder." For the student who tends toward "put downs", the role of "encourager" will represent a positive but gentler initial relationship to the group. The role of the "summarizer" is a wonderful one for the student who lags behind in academic work and needs more cognitive rehearsal. This role provides the opportunity for the special student to give the teacher the answers. For students who need an important, but easy-to-teach role, the "time-keeper" performs a special group task. This role also works well for students who slow the group down or are off task. There are hundreds of possible roles. Sets of them can be especially tailored to each individual difficult student.

An informal assessment at the Newfane Elementary School reveals that STS is a cost effective program. It appears to serve special students twice as well at half the cost. The performance of special education children has increased dramatically since STS was adopted, with a decrease in the number of staff members needed to serve the special needs population. Parents and teachers have noted the positive change in the outlook of our special students. They seem more confident, with better self-esteem. Another positive improvement pertains to issues of dignity and self worth among teachers, who grow more confident in the capacity to teach all children.

Personally, STS has shown me that creative thinking can be nurtured in a group learning environment that individually challenges students abilities. Through STS training I recognize that creative or critical thinking is not a skill to be taught and learned. Instead, it is acquired only when students are actively engaged in constructing and reconstructing their physical, social and moral worlds. With STS training, teachers can so empower all children, individually and together.

STS has helped me make science instruction meaningful and fun for special students. Moreover, STS techniques are particularly effective in reintegrating such children into the mainstream classroom. STS also has improved my teaching methods, by removing my fear of "having to know everything" and by showing me how to be a teacher and learner at the same time. Most importantly, I have learned to give my students a vision. I seek to impart to my students the value of critical thinking and the realization that, as future citizens ,they will have the power to make changes and the responsibility to do so.

THE CHESAPEAKE BAY: ENVIRONMENTAL EDUCATION FOR ALL AGES

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The Chesapeake Bay is a very visible, highly efficient natural resource which significantly impacts the economy of our region. As such it can serve as a very natural cornerstone for environmental education. The Bay's Watershed, shown below, encompasses all or part of Maryland, Virginia, West Virginia, Pennsylvania, New York, Delaware and the District of Columbia.

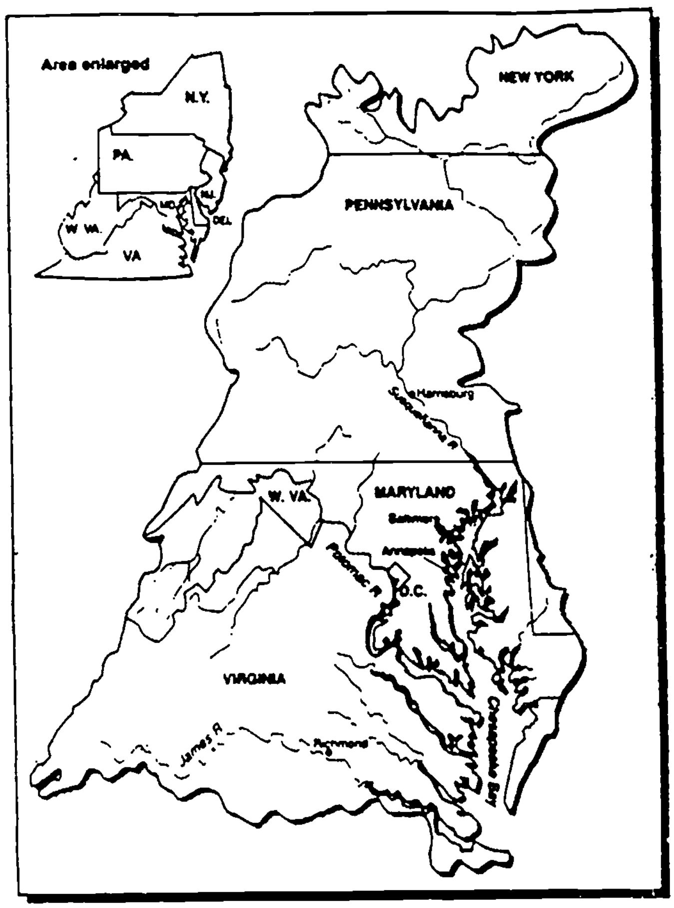

Figure 1. Chesapeake Bay Watershed

Our goal is to show how the Bay and its watershed can be used for environmental education and outreach within formal and informal educational settings. The Chesapeake Bay as an ecosystem is often used as a model for national and global policy decisions. Similarly, the programs that we have developed can be used as models for replication in other regions of the country.

Precollege Education

At Gettysburg High School in Pennsylvania, students are involved in classroom and extracurricular activities related to the Bay. Students can enroll in a nine-week Chesapeake Bay course as sophomores, juniors, or seniors. The course is entitled: "The Chesapeake Bay Independent Research Project." In the classroom, Gettysburg students learn about their local environment, the environment of their county (Adams), and the impact that their actions have on the Chesapeake Bay Watershed.

The fact that all the water that falls in Adams County ends up in the Bay is not lost on these students. They learn through classroom work, outreach activities, and various projects, that they as concerned citizens have a responsibility for solving the problems facing the Bay.

Adams County has traditionally been a rural, agricultural county in southcentral Pennsylvania. Local trends suggest the county will likely experience rapid residential development of areas that were formerly agricultural and riparian. Such developments will lead to degradation of local stream quality; in fact, some degradation of area streams may already have occurred.

The Chesapeake Bay Independent Research Project, ChIRPS, now in its eighth year, puts a practical perspective on classroom learning. Community problems can be identified and solved; students become environmentally aware citizens; and, through the various ChIRPS projects, students become involved in the community. ChIRPS students have given presentations to garden clubs, Grange meetings, church youth groups, and various service organizations. More importantly, these environmentally educated and environmentally conscious high school students serve as educators themselves in various elementary and middle school programs. The Gettysburg students have given Stream Study and Recycling Workshops each spring during Gettysburg's 6th grade outdoor education week camp.

ChIRPS students have also given a presentation on "Water Quality In Our Environment," to the 3rd grade class at a local elementary school and a Water Quality-Recycling Workshop for an area science teachers association meeting.

This program teaches these high school students about their local environment. It also serves to integrate science with citizenship and a commitment to the community. Many of these Gettysburg ChIRPS students continue to participate even after their formal nine week academic program through the Chesapeake Bay student group which meets after school and on weekends.

Chesapeake Bay Course Outline

I. Introduction to the Group Research Project Concept.

   A. What is the Group Research Project Concept?
   B. Teacher/Student Responsibilities.
   C. Environmental Issue Learning in the Classroom.

II. General Background Information.

   A. Pollution.
      1. Kinds of Pollution.
      2. Specific Types of Pollution.
      3. Resource Speakers and/or Field Trips.

   B. Adams County.
      1. Physical Features of Adams County.
      2. Major Land Uses in Adams County.
      3. Environmental Issues Important to the Future of Adams County.
      4. Resource Speakers and/or Field Trips.

   C. Chesapeake Bay.
      1. Physical Details of the Chesapeake Bay.
      2. Study of the Chesapeake Bay Drainage Basin.
      3. Orientation of Adams County to the Chesapeake Bay System.
      4. Resource Speakers and/or Field Trips.

III. Adopt and Design a Chesapeake Bay Project.

   A. Adopt a Chesapeake Bay Project.
   B. Design a Community Project Concerning Adams County and the Chesapeake Bay.

IV. Implement the Bay Project.

   A. Gather Data and/or Initiate Project.
   B. Interpret Results and/or Complete Project.

V. Finalization of Project.

   A. Present Community, School, and/or Student Programs.
   B. Enter State and National Contests with Project Results.
   C. Inform Scientific Societies of Project Findings.
   D. Continue with a Follow-up Program.

The Gettysburg High School Chesapeake Bay Students were featured in the Chesapeake Bay Video, "Local Solutions," produced by Pacific/East Creative Videos, Philadelphia, PA, March 1990. Earlier in 1989, WQED in Pittsburgh featured the Gettysburg High School Chesapeake Bay Students in a segment of "Conserving America's Coastlines."

The ChIRPS students were the first youth group ever to receive the Izaak Walton League of America Youth Conservation Award for Pennsylvania, Virginia and Maryland, 1988. Other honors include recognition by the National Wildlife Magazine in its feature, "People Who Make a Difference," August 1989.

These Chesapeake Bay kids have made an impact on their local community. They have also reached out globally. In spring 1991, Gettysburg high school students were responsible for putting in trust 5 acres of rainforest in the Program for Belize, Belize, Central America. The students have also established a pen pal environmental club relationship with two schools in Benaris, India. Various grants, some quite modest, others significantly larger, have helped support ChIRPS student activities. These have come from the Chesapeake Bay Education Mini-Grant Program, Department of Environmental Resources (DER), and from the Clean Water Act grant to Gettysburg High School, through the Adams County Conservation District.

Follow-up studies on the Gettysburg High School Chesapeake Bay students have shown that their projects, their studies, and their involvement have influenced their career and life choices. Over 60% of the active ChIRPS students declare college majors in areas dealing with environmental science and many of these alumni return to Gettysburg High School to help current ChIRPS students with their Bay-related workshops and programs.

Informal Education

Classroom education represents one mode of environmental education reaching a limited number of students during a prescribed period of time in their lives. Informal education though is broader and has the potential of reaching out on a continual basis to thousands of individuals of all ages and backgrounds.

The Calvert Marine Museum in Solomons, Maryland, is the product of a local community's desire and commitment to show and record a way of life.

Calvert Marine Museum (CMM) was started by the local community in October 1970. The first building was a small, 24 x 40 foot, building designed and built by volunteers. Cost for the building and exhibits was a little over $5,000. For the first five years of its life, CMM was a completely volunteer organization. From its humble beginnings in 1970, CMM has now grown to include ten buildings on its nine acre main campus and the J.C. Lore Oysterhouse a mile or so south on Solomons Island.

CMM is a public non-profit, educational, regionally oriented museum dedicated to the collection, preservation, research and interpretation of the cultural and natural history

of Southern Maryland. It has as its mission to interpret three marine themes: regional Miocene paleontology; estuarine life of the tidal Patuxent River and adjacent Chesapeake Bay; and maritime history of these waters.

The museum has exhibits on each of these three themes. There is a temporary paleontology hall, with a new 2,400 square foot hall scheduled for completion in late 1994. This hall will have recreated Miocene marine and terrestrial environments. The centerpiece will be a recreated giant great-white shark measuring 37 feet long. The exhibit will also include a recreated cliff face, a paleontologist's laboratory, and comparative collections accessible to the public.

In estuarine biology, CMM opened the partly completed exhibit, "Estuary Patuxent," in 1992. This exhibit when finished will include fifteen aquariums. "Estuary Patuxent" is designed to take the visitor on a walk up the Patuxent--from the mouth of the river to the fresh water marshes of Anne Arundel County Maryland. The exhibit is designed to highlight the different communities of plants and animals encountered on this journey. Some of the present and planned aquariums include:

- Chesapeake Bay-Cedar Point aquarium (3,500 gallons).
  This introduces the fish of the open Bay and the mouth of the Patuxent River.
- Submerged Aquatic Vegetation (SAV)-St. John's Creek aquarium (350 gallons). This exhibit shows the SAV community found in St. John's Creek.
- Oyster Bar-Helen Bar aquarium (400 gallons). This exhibit shows an oyster bar community modeled on the bar at the mouth of St. Helen's Creek.
- Salt Marsh-St. Leonard's Creek (1,000 gallons). This exhibit has a tidal salt marsh modeled on a marsh in St. Leonard's Creek.
- Blue Crab-Broomes Island aquarium (350 gallons). This exhibit focuses on the life history of the blue crab.
- Solomons Island aquarium (1,000 gallons). This exhibit recreates the plant and animal community which existed at the southern end of Solomons Island in 1950.
- Four feature aquariums, 50 gallons each, which display species difficult to maintain in the larger aquariums.
- Jelly Fish aquarium. When completed, this aquarium will contain sea nettles.
- Hunting Creek aquarium (1,000 gallons). This exhibit is on the tidal fresh water marshes.

- Freshwater Marsh-Jug Bay aquarium (1,000 gallons). This exhibit is on the tidal fresh water marshes.

- River Otter aquarium. When completed, this exhibit will include a 3,500 gallon aquarium and an outdoor enclosure. Visitors will be able to view the river otters both under and out of the water.

- Touch Tank. This is a shallow aquarium that allows visitors to touch snails, mud crabs, fiddler crabs, blue crabs and horseshoe crabs.

The Museum also has salt and fresh water marshes outside with interpretive trails. While the marshes are artificially produced, they are a unique educational resource. Students are able to compare and contrast fresh and salt water marshes that are within ten feet of each other.

In Maritime History, the museum has several exhibits. These include the Drum Point Lighthouse (circa 1889) and the museum's cruise boat, the *WM B. Tennison* (circa 1899). The J.C. Lore Oysterhouse (circa 1933) has exhibits on the oyster industry, regional fisheries, and deadrise work boat building traditions. The Small Craft Shed, an outdoor exhibit at CMM, shows local wooden work and pleasure boats. The exhibit, "The Maritime Patuxent: A River and Its People," opened in November 1989. This exhibit has over 500 artifacts covering three hundred years of local maritime history.

On the first floor of CMM, a Discovery Room is filled with fossils, books, plants, animals, and rocks. The Discovery Room seeks to draw visitors into an exploration guided by one's own interests and desires. This personal discovery process is facilitated by providing a space where minimal restrictions govern interactions between visitors and objects. A combination of activities draw the visitor in naturally; some activities are open-ended, while some are tightly focused on a single concept. Visitors are attracted to those activities that seem the most fun, and thereby make their own pathway through the Discovery Room. The impact of this process is increased by multiplying the senses engaged; objects are looked at, picked up, touched, smelled, and listened to.

In many of CMM's environmental educational programs, there are multiple goals. An attempt is made to show how cultural history and natural history are interrelated. The fourth grade oyster industry program or the school programs on local boat building traditions are not just history lessons. The philosophy is that it is very important to use material culture as a way of showing not just culture and technological change, but also economic pressures and resource depletion. Many of our ostensibly maritime programs are just as much about environmental change as they are about cultural changes. The view is that environmental education is not just a matter of science and engineering. Nor is it just a matter of current social policies. Rather, it is part of a longer historical pattern. If we do a program at CMM and a student thinks, "Gee, our ancestors made some stupid choices!", we have failed. We believe that it is important that students see why a choice, in the context it was made, seemed like the right one. The goals are to encourage children

to think in historic terms about environmental problems and to think about future consequences of their choices.

In the educational programs, an attempt is made to give children as many actual experiences as possible. In the fourth grade oyster industry program, we have the children hand tonging for oysters off our floating dock. The children also act out the different roles of shucking and canning oysters. In our school programs, we have the children out in our marshes looking at and handling as many of the plants and animals as possible. In the summer programs, we take students on sampling cruises on the *WM. B. Tennison*. Our goal is to make children feel more a part of the natural world around them, to make them more sensitive to the natural world, and to foster their interest in natural history.

A similar approach is taken in our teacher training programs. The approach has been a very pragmatic one. We have focused on the available resources for the teacher, classroom activities, collecting equipment you can make yourself, and field collection methods to use with classes. Our goal in these programs is to equip the elementary school teacher to take what we teach and to apply it immediately in the classroom, to help them to develop the confidence needed to pursue field work with their students, and to foster their interest in learning more about the natural history of the Bay.

Calvert Marine Museum is an institution that is a product of a community's desire to preserve itself and a way of life. The museum has taken on the mission of preserving a record of a place over time. The objective of environmental education at CMM is not to tell just about today's environmental condition, but to use our historical perspective to tell about the paths we took to get to today's environmental condition. We use the past to teach us and to guide us about the future choices we are to make.

Faculty Development: College and Precollege

The Chesapeake Bay provides an ecosystem which lends itself well to faculty professional development. A study of the Bay is interdisciplinary within the sciences; a study of the Bay is also intertwined with economics, natural resources, politics, and the culture of the region.

Prince George's Community College (PGCC) has been involved in Bay-related faculty professional development at both college and precollege levels. In 1991 PGCC received a Faculty Enhancement grant from the National Science Foundation to direct a June 1991 workshop on the Ecology of the Chesapeake Bay for 24 community college faculty from the watershed states. The six day workshop, held at the University of Maryland's Chesapeake Biological Laboratory (CBL), Solomons, MD, utilized CBL research faculty for lecture, field and laboratory work.

With additional support from the Chesapeake Bay Trust and the Spectroscopy Society of Pittsburgh, a set of 80 slides with narrative, "The Chesapeake Bay: Seeking a New Equilibrium," was developed. A videoconference on the Bay, October 1991, was developed by PGCC and beamed to 46 sites in seven states, reaching over 10,000 persons.

A photography exhibit on the Bay, "Biology, Art and the Bay," was developed in fall 1991 for the PGCC Library building. A continuation grant from NSF in summer 1992 provided for continuation of these activities.

Under this continuation grant, five of the original 24 workshop participants, faculty from Charles County Community College, Essex Community College, and Prince George's Community College in Maryland, Germanna Community College in Virginia, and Reading Area Community College in Pennsylvania are working to develop laboratory activities and field exercises for a Chesapeake Bay manual which will be distributed to the 86 community colleges in the watershed region. Production date for this manual is set for July 1993.

The goals of the individual projects range from a study of sediment buildup over time by a geographer from PGCC to the development of laboratory exercises which would enable students to make field measurements on respiration rates and dissolved oxygen by a biologist from Germanna Community College. Each of these projects will be Bay-related but linked to the local environment.

The development of an interactive videodisc on the Bay is also underway through this continuation phase of the NSF program. Work is ongoing at Reading Area Community College on this facet of the program. The interactive videodisc will includes photographs showing current Bay conditions, environmental changes over time within the watershed, and fish, ducks, and invertebrates.

Technical content for the original July 1991 workshop focused on the Bay as a Coastal Ecosystem, Nutrient Budgets, and Hydroacoustics. Lectures were supported by day-long field activities aboard the research vessels, The *Aquarius* and the *Leidy*. All 24 workshop participants were housed at Solomons allowing for extensive interaction within and outside the scheduled activities. One evening lecture dealt with the Chesapeake Critical Areas program while the Saturday program brought in various speakers who discussed how to integrate the Bay into the curriculum.

All these activities have led to additional professional interactions between various community colleges and between the community colleges and the research community at CBL.

At the precollege level, PGCC has developed summer teacher training institutes to upgrade the content knowledge of county elementary science teachers. The first of these was held in summer 1987. Last summer, with funding from the Maryland Higher Education Commission, PGCC held four teacher training institutes for eighty teachers. These were in chemistry, the life sciences, the physical sciences, and environmental science. All institutes were two to three weeks in length.

Elementary teachers who are accepted for the Environmental Science Institute must have completed one or more of the other summers science institutes. Thus, the teachers involved in this institute have a stronger scientific background than many of those in the othe institutes.

Within the environmental science summer institute, elementary teachers get a broad overview of environmental science. A significant amount of time is spent on the Chesapeake Bay since we are very close to the Bay. Bay-focused activities include a trip to the Calvert Marine Museum and a half-day cruise aboard a research vessel at CBL. Thus, the contacts that were made through our college NSF program have been maintained and utilized at the precollege level.

With additional support from the Chesapeake Bay Trust, three of our PGCC faculty have developed an environmental resource guide for elementary teachers (Sinex, Panyon, and Lauffer, 1992.) This guide is geared at the local level. It provides background on available resources, teacher-developed lesson plans, and directions for making inexpensive sampling and field equipment. Additional copies are available from the Science and Technology Resource Center, PGCC.

The Future

The Chesapeake is still one of our country's most valuable resources, providing millions of pounds of seafood annually. Its blue crab production makes the Chesapeake the largest blue crab producer in the world. The Bay also serves as a major commercial waterway and a natural habitat for wildlife. For our students, both young and old, it is a continuing source of recreational pleasure.

As the largest estuary in the contiguous United States, the Bay and its watershed are subject to the pressures of human activity. Comprehensive solutions are often needed to the conflicting demands on the Bay's resources. A study of the Bay ecosystem can serve as the model for a study of these very complex environmental problems.

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A COMPREHESIVE SCHOOL-WIDE SOLID WASTE PROGRAM

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Dealing with solid waste is a perplexing problem. In both urban and rural areas landfills are closing and the cost of garbage service has risen dramatically. Recycling provides a flexible alternative to many aspects of the garbage crisis, especially when combined with source reduction activities and biodegradable waste composting. As part of a comprehensive solid waste program these strategies can effectively keep a large percentage of solid waste from ending up in landfills, incinerators or burn barrels.

At Mt. Baker High School in Deming, Washington, these problems are being addressed by students, faculty and staff through multi-disciplinary action-oriented research projects. Thematic teaching that crosses curricular lines is coupled with a problem-solving model that allows high school students to practice district-wide recycling, composting, waste stream analysis, and environmental monitoring. Virtually all school personnel are attacking these real world problems from different curricular perspectives. Emanating from unimposing origins, this single project has created a viable, working model for school-wide curriculum integration, increased collaboration, and holistic learning for a sustainable future.

History of the Project

The model program evolved from very modest roots in an elementary school resource room as part of a project designed to facilitate problem solving and higher level thinking skills in able learning students. A mini-recycling center started by these elementary students was quickly noticed by the Washington State Department of Ecology (DOE) and

rewarded with a $500 grant. The money was "recycled" back into the program through collaboration with our high school Vocational Agriculture (Vo-Ag) and Future Farmers of America (FFA) students. Together, these two programs encouraged the school district administration to purchase paper recycling bins for each classroom and work station in the district. Further, a grant from the state Ecology Youth Corp paid for a crew leader and four students to manage the expanded recycling program. In its third year of operation a unique composting program was developed. A composting site was constructed by students using recycled wooden pallets covered by a tin roof. This low-technology facility allowed students to compost over four TONS of food waste and animal bedding. This effort was rewarded with a $5000 DOE grant to upgrade the entire project significantly. In fact, technology and Vo-Ag students designed and constructed a state-of-the-art indoor composting facility near our school barn that includes a huge 3-cubic yard capacity composting digester. The entire facility is now used for action-oriented research projects.

The Multidisciplinary "Connections Project"

Two concurrent and seemingly unrelated projects provided the stimulus for multidisciplinary curriculum integration between traditionally separate vocational and academic departments. One project, funded through the GTE GIFT Grant program, allowed a chemistry teacher to establish a heavy metal environmental monitoring program at the school. Another grant, also a GTE GIFT Grant, allowed a biology teacher to established a composting program. The "Connections Project", born when groups of teachers started brainstorming possibilities for integrated thematic instructional strategies, resulted in an entirely nontraditional way of providing educational access for all students.

The "Connections Project", currently funded by an EPA grant (Vollendorff, et al., 1992), taps the strengths of many types of teachers in our school (see Figure 1). Technology students monitor the composting equipment and "invent" workable improvements as needed. Accounting students track expenditures of grant monies and program income from the sale of recyclables. Vo-Ag students, responsible for the facility

construction and compost activities, collaborate with members of the Nooksack Indian Tribe to develop an efficient raw materials collection system for recyclables and food waste throughout the school district and nearby Tribal Center. Shredded waste paper used as animal bedding for livestock at the barn is also composted along with food waste from school district kitchens. These students use math skills to chart the ratio of bedding to kitchen waste and are searching for an ideal composting ratio that will sustain a temperature of 150°F (Golueke, 1972). Using computers, math analysis and algebra students process data collected from various phases of the program and perform statistical analyses related to biological and chemical parameters.

Biology and chemistry students monitor noxious gas production, heavy metal content, nutrient content, moisture level, pH, temperature and certain micro-organism levels. The monitoring of all parameters follows specific protocols developed specifically by teachers and tested by students (see Note 1 below). Chemistry students are now conducting biological oxygen demand (BOD) and chemical oxygen demand (COD) tests on the compost to map oxygen uptake. Biology students have developed a number of composting method protocols and are gearing up to do selective assays for various pathogens. Here again, all data processing and handling is done on computers.

Horticulture students utilize the finished compost product for investigations on crop yield, biological activity in soils, and earthworm counts in test plots. These students use their findings to disseminate information to local community groups through presentations and booster club activities.

Art students have constructed posters to advertise recycling and composting at district schools and throughout the community. Social studies students have directed their efforts toward developing strategies to change community beliefs about garbage creation and disposal. They developed a community survey to measure personal values and present feelings about the garbage crisis. Other surveys will follow and educational awareness programs are planned. A.ticles written by sophomore English students have appeared in a local newspaper and a school newspaper "Recycling Times" is now up and running. The

Information Processing class will be responsible for preparing the final report that must be submitted to EPA at the close of the grant project. A media student is producing a video depicting the project from the early building stages to its completion in June. This video will be available to other high schools interested in replicating the project.

The "Connections Project" is a unique approach to thematic multidisciplinary teaching. From an environmental education perspective, it is unique in that most school programs are self-contained in a single classroom. Although a systematic study has not been attempted to assess program impact on student beliefs concerning garbage-handling techniques, all school personnel have indicated two fundamental changes among both **students** and **teachers**. First, a unique kind of modeling has resulted in a majority of people on campus recycling wastes appropriately. Students and staff are cooperatively solving "our own" garbage problem. Secondly, students are experiencing a holistic type of education that will definitely remain with them after they leave Mt. Baker High School. It is apparent that students are making educational connections between fields or disciplines that, until recently, were not related at all.

We are examining garbage from beginning to end. Students conduct waste stream analyses of their **own** lunch. They are sorting it, recycling part of it, and composting the rest. They have found the science of a solid waste stream to be fascinating! Biology students are introduced to cycles "hands-on and thematically. Our students are developing a clear understanding that solid waste problems are created by all of us and therefore must be solved by all of us. We hope this experience will be a good introduction to a self-sustained lifestyle.

Student ownership will continue to exist through the development of more elaborate experimental protocols, more intensive monitoring tasks, and economic challenges. For an added incentive the Associated Student Body is allowed to reclaim all extra money the school saves from garbage hauling.

The Technology Component

An action-oriented student research program requires elaborate use of technology tools. Fortunately, since our campus facility is new and equipped with an MS DOS internal network of computers, students can tackle a number of tasks efficiently. All students write their proposals using word processors, create databases and spreadsheets to handle their collected data, use graphical techniques to process data, and some of the students have been introduced to mathematical modeling techniques--all focusing on the composting process. They have learned how to create beautiful finished reports. We anticipate more use of technology tools such as CD ROM information retrieval in our problem-solving phase, multimedia document production as part of class projects, and external communication networking with other schools, industry partners, and university scientists.

Sustaining Partnerships and Grants

This project has been the vehicle to establish working partnerships with a number of local community and state agencies. Among them are the Nooksack Indian Tribe, Washington State Department of Ecology, the Environmental Protection Agency, Western Washington University, and Georgia-Pacific Corporation. The partnership has opened new doors for students to sample career opportunities. For example, chemistry students routinely take samples to WWU to analyze on an atomic absorption spectrometer. They will be conducting the COD tests in quality control labs at Georgia-Pacific Corporation under the direction of trained scientists.

Similarly, grant writing was a new experience for most of us. Through this process we entered a new level of professional development that has also strengthened our collaborative group working skills. We did quite well in generating funds for our school.

Opportunities for the Future

Our goal is to have 100% of the student body actively involved through various class projects in the "Connections Program". At present, only some of our students experience more than one phase of our solid waste program. We plan to continually "recruit" students and teachers into our thematic conception of learning. We have planned a one-day school "solid waste" conference complete with student exhibits, breakout sessions, paper presentations, community involvement, and a career emphasis. Hopefully, gradual incorporation of this program into our junior high school and elementary schools will occur.

Throughout this project we have used a problem-solving model developed by one of our faculty members that encourages students to help make permanent changes in a community (see Figure 2). According to this model, through a sequence of individual and group actions, students can work through a specific problem to arrive at a reasonable working solution (see NOTE 2). Our next goal is to apply this problem-solving model to community barriers of solid waste management. We believe that if students become community problem solvers they truly will be claiming ownership for the entire project.

Final Vision

Students at Mt. Baker High School are beginning to understand what their responsibility as LEARNERS entails. They have been given an opportunity to make positive choices that will affect their future. Success or failure of this program is both an individual challenge and a team effort. From an individual perspective this program offers hope and alternatives for both individual creative learners and "at risk" students. Many learning styles can be built into this thematic process. Secondly, cooperative team effort and team building play important roles in the project. Not too many traditional educational programs can offer that variability. Failure is only temporary. New problem-solving ideas are encouraged and immediately

rise to an action stage. Students are working to break down societal barriers regarding both the garbage issue and education in general.

Finally, from an educational viewpoint, students have taken a big step toward realizing that all problems, all on-the-job tasks, and even most personal decisions **require** collaborative efforts by a number of individuals and **affect** the actions of many other people nearby. This global awareness of citizen responsibility and action is a new and necessary, untapped parameter of educational thought for the future. Hopefully, the experiences gained from participation in this project will strengthen further the cohesiveness in other school programs and people.

FIGURE 1: Thematic Connections

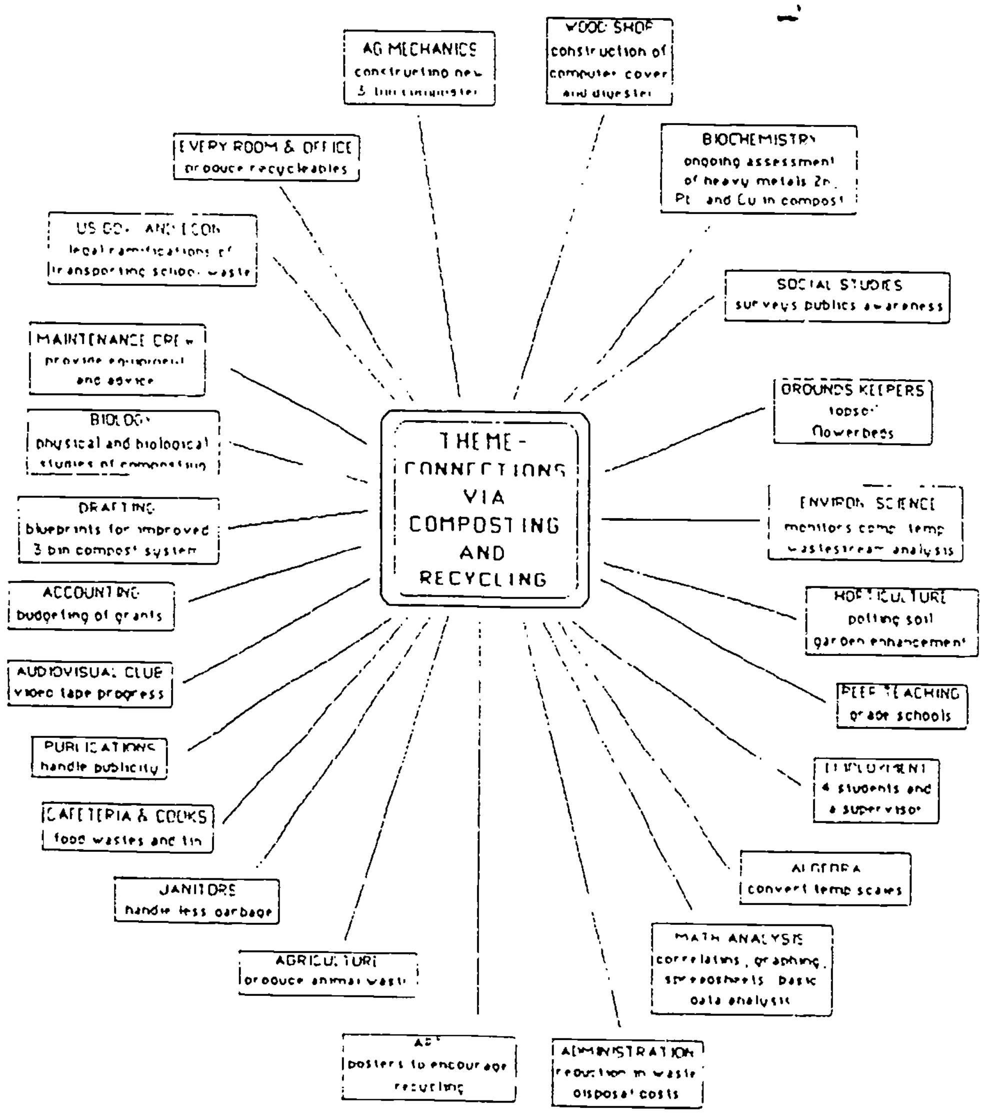

FIGURE 2: Real-World Problem Solving

PHASE 1: Exploring the present situation

A. Identifying and understanding assumptions
B. Identifying and understanding consequences
1. Personal
2. Economical
3. Political
4. Environmental

PHASE 2: Investigating the present situation. Action plan

A. Obtaining baseline data
B. Writing a briefing document

PHASE 3: Defining and implementing a solution

A. Selecting a specific solution direction
B. Identifying and stating a specific problem
C. Identifying and mobilizing stakeholders
D. Identifying and involving policy makers
E. Establishing a committment
F. Drafting a policy statement
G. Implementing personal action
H. Implementing group action

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NOTES

NOTE 1: All chemistry and biology protocols will be provided upon request. Send request to David C. Tucker, Mt. Baker HS, Deming, Wa., 98244

NOTE 2: This problem-solving model was developed by David Tucker for use in his STS Chemistry and Biochemistry programs and has been presented nationally at numerous conferences, most recently at the 7th TLC Conference, Arlington, Va., 1992.

SITING A HIGHWAY: AN STS SIMULATION

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Social studies teachers have used simulations for many years to provide practical opportunities for students to appropriately apply social studies concepts in a simulated environment. As the STS movement has gained currency in K-12 schools, increasing numbers of teachers within various school disciplines have been using STS simulations (Parisi, 1989a, 1989b, 1990; Ramsey, Hungerford, and Volk, 1990).

We present here one simulation which has been developed within a module produced by the New York Science, Technology and Society Education Project (NYSTEP). NYSTEP is a collaborative partnership between the New York State Education Department, the New York Power Pool, and the Atmospheric Sciences Research Center of the State University of New York at Albany (Valentine, 1989; Peruzzi, 1991; Peruzzi and Cheek, 1992). Major outside funding for the project comes from the National Science Foundation under the Private Sector Partnerships Program. Several NYSTEP modules feature simulations as one activity among many which teachers can use to foster STS understandings and applications among students.

This highway siting simulation is taken from the NYSTEP module, Using Earth's Resources: What are the Tradeoffs? Problem-Solving Activities for Middle-Level Science, released in 1992. The module consists of three units focused on the following topics: our location on the land, soils and mineral resources, and local stewardship. Eight activities within these units introduce students to:

- various types of human activities which occur on land in their immediate vicinity and the tradeoffs associated with such uses
- important properties of soils
- development of a soil profile
- minerals
- our dependence on soils and minerals
- amelioration of soil erosion and its problems

The remaining portions of the module suggest ways to use relational databases in the study of land use, soils, and mineral resources; bibliographic resources and lists of associations to contact for further information; relevant computer software and

audio-visual resources; and sample quotations concerning land use, soils, and mineral resources.

The three-part simulation, appearing at the end of each unit within the module, is used to conceptually tie the module together for students and the teacher. Each portion of the simulation builds upon the previous part(s). Student success within the simulation portions can only be realized by accessing and using knowledge and concepts which have been assimilated from studying topics within the current unit and preceding unit(s).

Only the first part of the simulation is reproduced in the pages which follow. Residents outside of New York State who are interested in purchasing one or more copies of the entire module should contact the NYSTEP office for ordering information. Modules within New York State are distributed to middle-level science teachers through attendance at a NYSTEP workshop offered by the statewide network of NYSTEP Resource Agents. Eligible New York State teachers should contact the NYSTEP office for information on workshop offerings in their local area.

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1.3

WHAT ARE THE LOCAL TRADEOFFS IN LIVING WHERE WE DO?

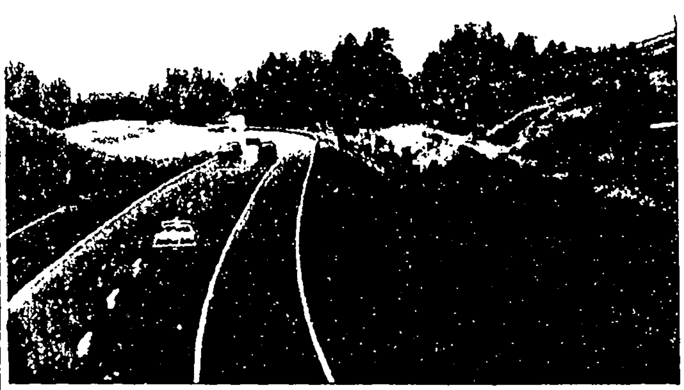
SYLLABUS IMPLEMENTATION

LEARNING OUTCOME

■ *Students develop a preliminary community development plan for a simulated community that faces changes due to a proposed highway.*

INSTRUCTIONAL MODEL FOCUS

Planning



Lesa Clark

SKILLS DEVELOPMENT

■ ***communicating information*** *: Students explain the tradeoffs represented by the locations of their respective communities.*

■ ***negotiating*** *: Students negotiate community development plans with other (class) communities.*

Classroom Activity

1. Inform students that you will be beginning a simulation. If the class has not participated in a simulation previously, introduce the concept. Elicit several examples of simulations from students, and discuss their value.

2. Tell students that they will be asked to return to this simulation at two other points during the study of this topic. Distribute to all students the topographic map of Empire County and the overlay map of communities. Give students some time to study the maps. Have each student develop a cross-sectional profile of one transect across the county.

3. In the simulation, residents of the city of Empire will equal the combined total of residents for the other five communities. Randomly assign students to one of the six communities, weighted to favor the city of Empire, until all students have been assigned. Give each student a copy of the role card designed for the residents of the particular community to which he or she has been assigned. Allow students to discuss their role with other members of their community. Using the map, each community's residents should draw up a list of the benefits and burdens associated with where they live. Each group should also produce a cross-sectional profile for their portion of the county. A spokesperson from each community should then explain the list to the rest of the class.

4. Read to students (and post for their future reference) the history of Empire County and inform them of the proposed building of an interstate highway through the county. Provide each community with a blank transparency sheet. Point out on the overlay map the two existing interstate highways that must be joined by a new interstate. Ask communities to evaluate their situation in

ATTITUDE FORMATION

■ ***Respecting the rights of others in using resources (A2.32) :*** *Students from different communities negotiate their development plans in light of their needs and the needs of other communities.*

CONTENT UNDERSTANDINGS

■ ***Decision making about a complex issue involves tradeoffs (J20) :*** *Students identify the tradeoffs represented by the location of their simulated communities in the county.*

■ ***Use of any nonrenewable or renewable [resource] has advantages and disadvantages associated with its use (I28) :*** *Students negotiate with other communities about the use of various resources within the county.*

CONCEPTUAL CHANGE

The concept of tradeoffs can be reinforced for students by having them keep running lists of benefits and burdens associated with their everyday activities—within and outside of school. Their lists can also be the basis for a discussion of short- versus long-term benefits and burdens (tradeoffs) and how the differences in time scale are a factor in decision making.

regard to the need to build the interstate highway. They should note and explain any changes in their earlier list of benefits and burdens. They can use the blank transparency to indicate one or more possible routes they believe are optimal for the connecting highway.

5. Have each community formulate a community development plan that will guide the community in its negotiations with other communities about the location of the interstate highway. Each community should carefully consider its options and create one or more possible routes for the interstate within the county. To develop viable plans, communities should freely hold consensus-seeking meetings with their own residents and those from other communities. Each community plan, when finalized through negotiation, should be written up and posted for all other communities to read.

Supplementary Information

Materials

- maps of Empire County (one per student)
- copies of overlays (one set of transparencies per community)
- transparencies and nonpermanent transparency pens

Advance Preparation

Prepare copies of the base map and the overlays. If students have not been involved in simulations prior to this activity, engage them in a simple one as a preparation activity.

Choose a topic germane to the situation within your local school, for example, contracting food services to a private vendor. Have a few students spend a few minutes playing various roles in a simulated school board meeting.

Procedural Notes

This introductory simulation activity raises student awareness about the unavoidable tradeoffs inherent in land use decisions. Students will return to this simulation at the end of each of the remaining two units. During the next unit students will acquire scientific information concerning soils and minerals. They will then receive additional information about the soils and mineral resources of Empire County. The simulation

Extensions

The simulation can be made more elaborate . The map of bedrock geology has been provided for optional use. You can also make up roles for the students within a particular community that represent divergent local interests. For example, a resident of Patroon Acres could be the owner of the Empire Quarries, owner of a business in Empire, or the owner of land elsewhere in the county.

Evaluation

Student groups, representing communities with different economies and land use patterns, will be able to formulate plans for future development of their communities.

COOPERATIVE LEARNING

Some communities within the simulation may need explicit instruction to help them decide upon appropriate roles for all community members. Build into the activity appropriate group accountability procedures so that every person in every community is contributing to the effort.

portion of the next unit will provide an opportunity for students to apply the scientific concepts and understandings they have learned.

Use a transparency master and overhead or opaque projector to create a large map of Empire County. The necessary overlays can be produced in similar fashion as you return to the simulation in Activities 2.6 and 3.2, when additional complicating factors are introduced. It would also be useful to have students create a three-dimensional scale model of the county that they can use for this activity and all subsequent activities within the simulation. These activities will provide opportunities to teach about the science concepts of two- versus three-dimensional space and to expand previous discussions regarding topography, contour lines, and elevation above sea level.

Provide a bulletin board so that the six communities can post notices, plans, etc. as they develop. You can also use it to post updated information of interest to all communities.

Students can be assigned to one of the communities by using numbers drawn from a hat. Randomness in the selection process will help ensure diverse talents within each community.

Community development plans should generally exhibit the following characteristics:

- fidelity to the physical features of the local area
- a timeline for various development changes
- sufficient flexibility to deal with changing demographics and economics
- no planned activities which adversely affect surrounding communities in major ways.

Interdisciplinary Connections

Activities that focus on tradeoffs inherent in the location of communities:

- **Technology:** Interview one or more local civil engineers to find out how technology can ease the burdens of a particular plot of land. Using land fill that has been brought in from another area is one example of how technology may be used to alleviate difficulties.
- **Social Studies:** Obtain past land use patterns of your local area from a local historical society, and try to determine what some of the tradeoffs would have been during a particular time period.
- **Language Arts:** Compose a poem that highlights key tradeoffs in your current neighborhood--including some related to the land.
- **Mathematics:** Within the simulation, develop a criterion-weighted system to use in assessing tradeoffs facing your community.
- **Health:** Document how frequently health considerations surface as the various communities develop their lists of benefits and burdens and their long-range community development plans. Account for the presence or absence of health considerations.
- **Home and Career Skills:** Investigate careers in public planning, especially those that involve active consideration of tradeoffs facing communities. / Discuss with members of your household the tradeoffs of living where you do.
- **Art:** Paint a picture that symbolizes for you the tradeoffs represented by your local community. / Compose a rap that recounts the benefits and burdens that your community identified within the simulation.
- **Foreign Languages and Cultures:** Interview local residents who emigrated from other nations regarding the tradeoffs that faced them in choosing to come to the United States.

Scenario

Empire County has a long and rich history. There is archaeological evidence of early Native American settlement within the area. Dutch settlers moved into the area in the seventeenth century, building the first European settlement in what is today Patroon Acres. Abundant water and fertile land on the Iroquois River floodplain in the northeast part of the county made the area particularly attractive.

A series of epidemics is believed to have decimated the Native American population. After the War of Independence, more English-speaking settlers began to arrive in the county. Farm goods were the main commodities. During the Industrial Revolution mills of various types were erected along rivers and streams within the county, and many small limestone quarries commenced operation.

In the nineteenth century the county experienced steady growth with an influx of immigrants from Western and Central Europe and free Blacks who migrated to the area. The city of Empire was duly incorporated. The county's economy became more diversified and light industry increased. Advancing technology made large-scale mineral mining feasible for the area, and the Empire Quarry Company began operation. Advancing farm technologies, as well as agricultural lime produced from area limestone, more than tripled the crop yield of the area's farms. Local farmers became very prosperous. Local dairy farmers formed an agricultural cooperative toward the end of the century to control quality and to guarantee better market prices.

Empire County weathered the difficulties of the Depression years with the population remaining stable. Local residents believe the county's economic stability during this period was due to the mix of farm and manufacturing products. Local politicians still value this economic diversity and strive to create policies that encourage a mixture of many different types of business and industry.

The county today enjoys a sound economic base that supports 150,000 residents. Median income for the county is above the national and state average, although there is a wide range in socioeconomic status across the county. Many ethnic and racial backgrounds are represented in the population. Half of the county's residents live within the city of Empire. The remaining population is concentrated in five areas within the county. The largest employer in the area is Empire Quarry Company.

The state has recently announced plans to run a major interstate highway through the county, to link two existing interstates. While the county is fighting the state's plans in court, it appears unlikely that the lower court decision favoring the state will be overturned on appeal. Local businesses and residents have been told that the interstate highway will be built through the county sometime over the next three years.

The exact route of the highway has not been determined. It is certain that the entire length of the highway will have to pass through Empire County.

Local Community Descriptions

City of Empire: Founded over a hundred years ago, Empire is the county seat and the economic center of the county. Its 75,000 residents live primarily in single-unit dwellings along spacious, tree-lined streets. A series of small apartment buildings, built over the past decade, provide shelter for low-income families. The escarpment and plateau to the west of the city and the wide, flat plain that continues to the east and south are valued by residents, who enjoy diverse scenery unsurpassed within a three-state area.

Empire Estates: A series of townhouses and small apartment complexes comprise the community of Empire Estates.

Empire Agricultural District: The rambling farm homes within this community and the rich, fertile fields surrounding them remind county residents of the importance of agriculture within the local economy. A few farms are very prosperous; the remainder provide a suitable living, but no one is growing rich.

Valley View Estates: Valley View consists of Swiss-style homes built in the early 1980s. Residents can see for miles to the east due to the elevation.

Dutch Village: This is the newest community. Many of its residents work in Eindhoven, a large town in the adjacent county. They choose to live in Empire County because of lower housing costs and a more rustic environment.

Patroon Acres: The oldest continuous settlement in the county, Patroon Acres is composed of Georgian houses that are over 100 years old. Several have been designated National Historical Landmarks and are protected by Federal

laws. A significant number of these homes are in dilapidated condition and serve as residences for some of the poorer residents within the county, including a large number of elderly persons.

Important Local Industries

Empire Technology Park (ETP): Built in the early 1980s, this light industrial park has brought a tremendous boost to the local economy. Its high-tech products are sold statewide and nationally. Contract negotiations are under way for several lucrative international contracts that could mean additional jobs, money, and building expansion for the Park.

Empire Quarry Company: This locally owned and operated company employs 25% of the total population within the county. Crushed stone from the quarries is highly prized throughout the eastern portion of the state and is used to produce good quality cement and concrete products. Business has been steady, and many families have been with the company for three generations.

Map Information

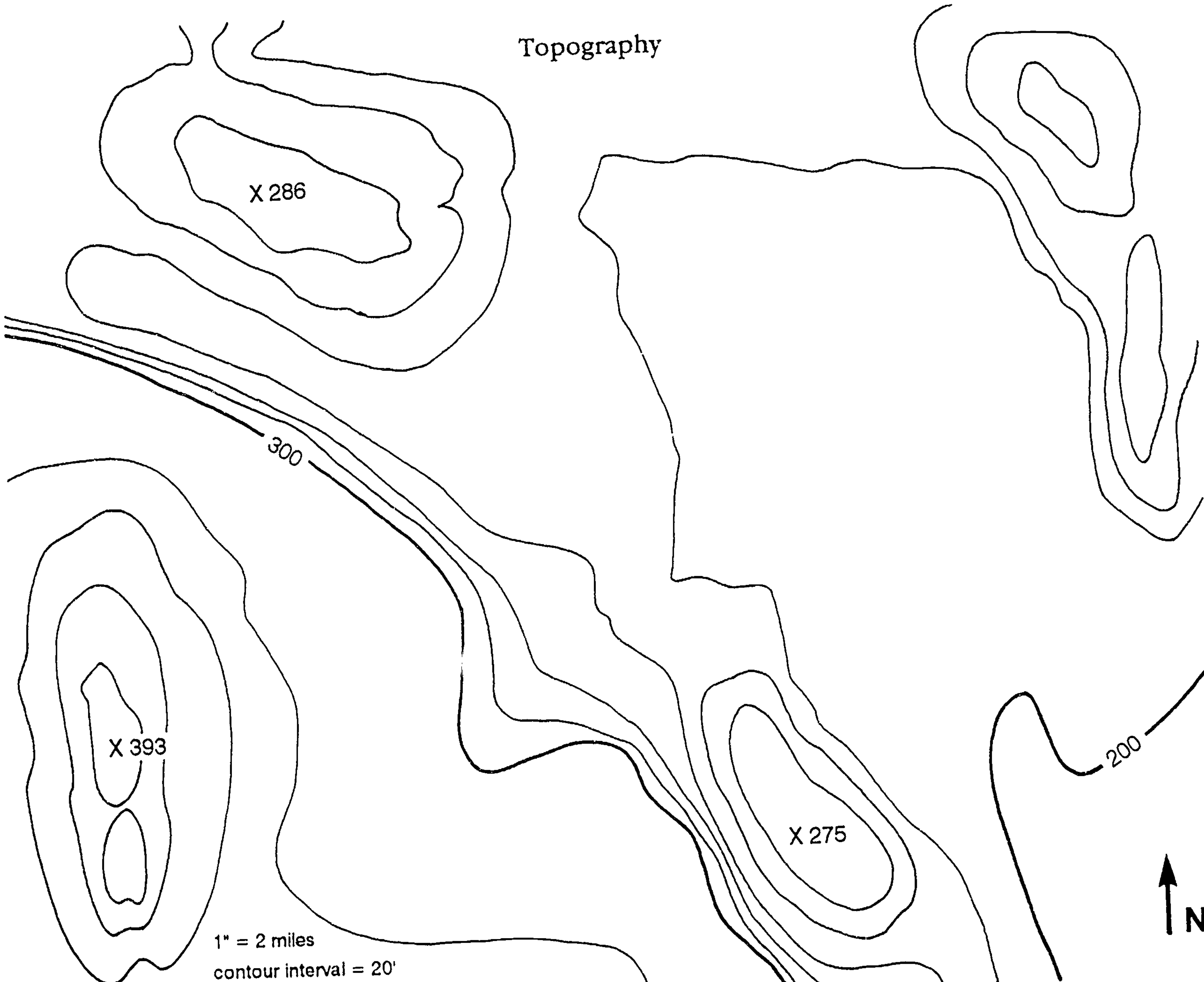
Topographic Map

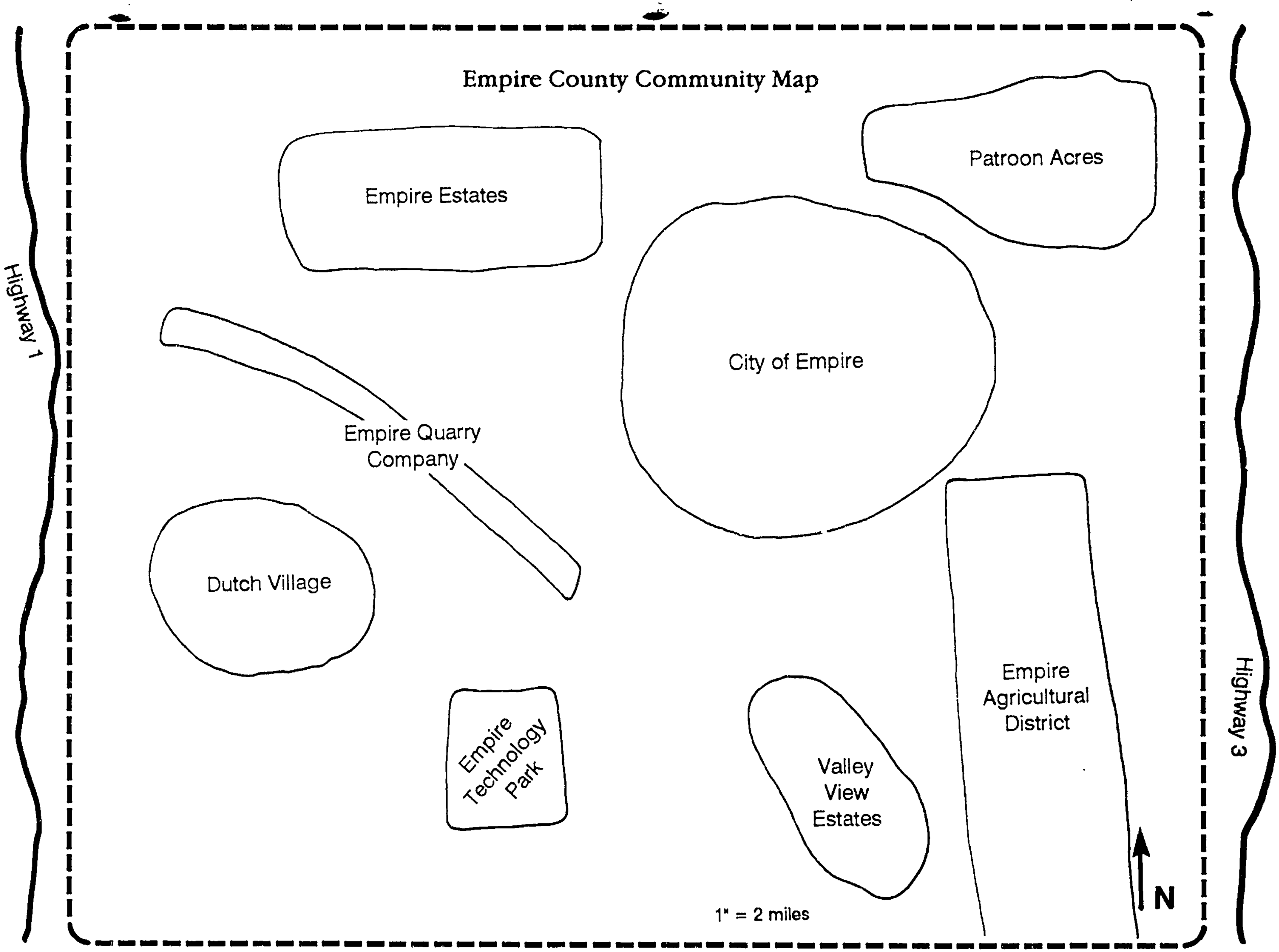
Scale: 1"= 2 miles
Contour interval: 20'

Bedrock Geology Map (optional)

A - sandstone; sand-size quartz, suitable for road building stone
B - shale
C - limestone with gypsum beds
D - shale
E - granite with mineral veins

Topography





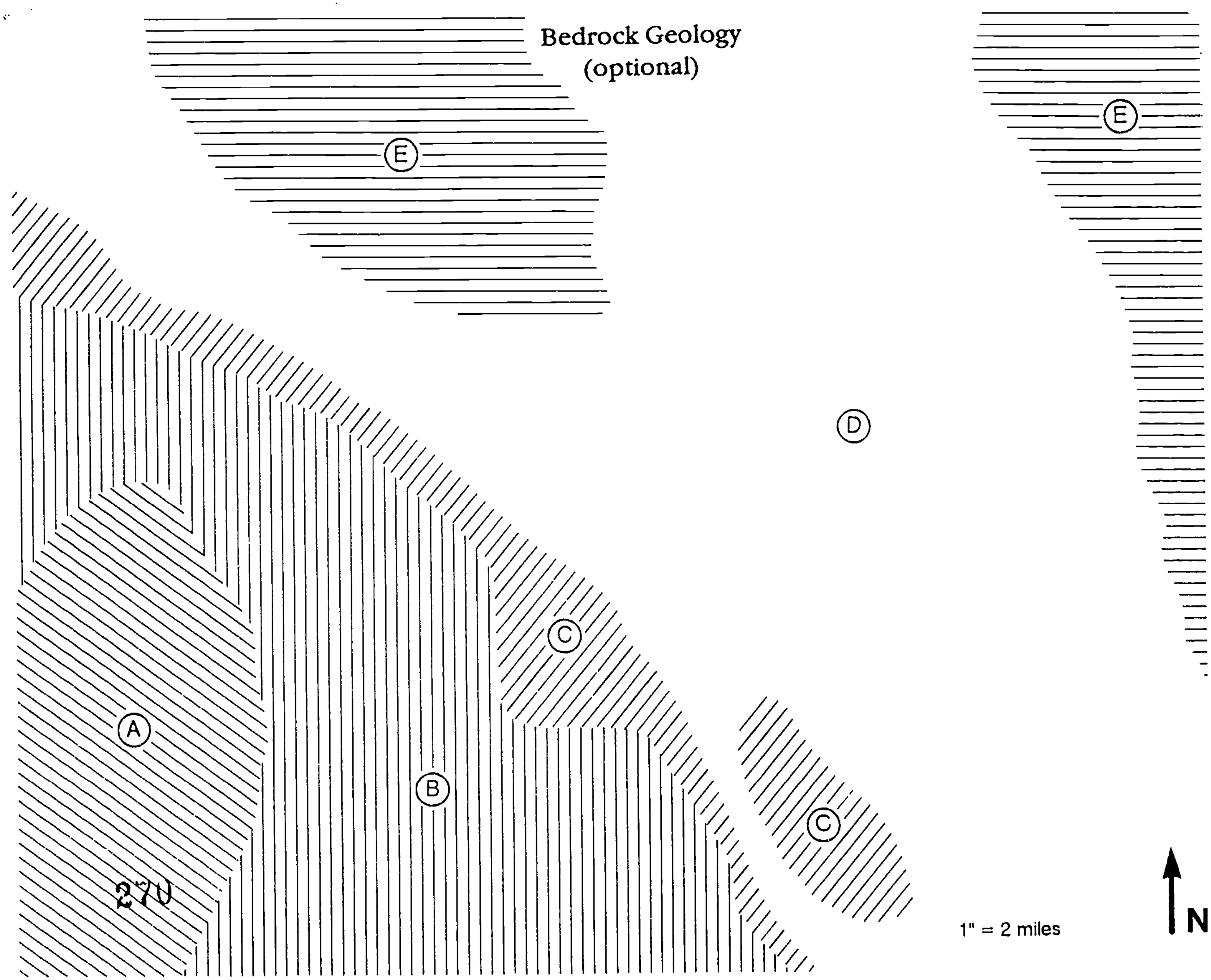
Empire County Community Map
Empire Estates
Patroon Acres
City of Empire
Empire Quarry Company
Dutch Village
Empire Technology Park
Valley View Estates
Empire Agricultural District
Highway 1
Highway 3
N
1" = 2 miles

246j

268

269

246k



YOUNG CHILDREN AND SCIENCE: MATERIALS MATTER!

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Imagine a classroom where children are excitedly hypothesizing what will happen if they change the materials, and/or the structure for the Three Little Pigs Houses. Now imagine a group of young children constructing a bed for Goldilocks out of found and recycled materials. All too frequently national reports bemoan not only the state of children's knowledge in science, but also the state of science education across the United States. All too frequently educators and teachers lament the shortage of time, meager resources, lack of confidence as reasons for not "teaching" science to young children. Hopefully this presentation will demystify science experiences for young children, by providing new curriculum approaches, by suggesting different strategies, by supporting an integrated broad-based interactive program. It shores up the teacher's self-confidence, it permits flexibility in styles of learning, and in styles of teaching.

The spark that turns on both the teacher and these young children is the plethora of exploratory activities and approaches which permit these young children to actively experience and interact with materials, and to develop a course of action which impacts positively upon a problem. For example, young children assemble themselves into a small group and dramatize the wolf blowing down a house of straw,...is it possible...they actually "construct" a house of straw and blow it down...questions follow:...what could the pig have done to make it stronger...could we try it...did it work...can we improve on it. Thus all the activities are directed toward developing an understanding and awareness of materials while reaching out for children for their creative solutions and abounding energy. Not only do the children find themselves empowered through their impact and involvement, but the teachers feel empowered also - they become the catalyst for change. Their view of the role of science in young children's lives is dramatically altered. Their view of how young children learn science is reinforced and supported. Their view of themselves as agents of change is incredibly strengthened.

The following explorations were offered to children in kindergarten, first and second grades, only after these children had had a myriad of opportunities to interact with all kinds of materials (matter). After many, extensive hands-on activities (both informal and structured activities) where children would discuss their findings, write down their thoughts and observations and arrive at some common generalizations about the material they were exploring -- sand, water, soil, cardboard, shells, foam, pine cones, hay, grass, etc. -- we suggested moving them along the continuum so that they could begin to apply what they had learned to new situations. It cannot be stressed enough that we must help children document their findings and observations. This is a crucial segment of the children's own work and retention of concepts.

Because we believe that content, skills, knowledge, indeed, all learnings are connected, we always strive for an interdisciplinary approach in our teachings of new concepts which are dependent on a prior knowledge and generalizations. For instance, the following explorations utilize familiar Mother Goose nursery tales. What better way to fuse literature and science than by reading these tales and experimenting with "materials" and "stuff" in order to "test" the assumptions implicit in these tales.

Exploration #1

The Three Bears have decided to build a weekend home in the mountains. They want to have three new beds made for their new home, in addition to one for a guest room, so that Goldilocks would be able to sleep over.

Remember:
Father Bear likes a hard bed
Mother Bear likes a soft bed
Baby Bear likes one just in between - not too hard, not too soft

Bonus: You are Goldilocks; you will design your own bed

Activity: To design 3 or 4 new beds

Materials: For younger children, place assorted trays of materials on their tables. Buttons, rug scraps, corks, pine cones, straws, tissues, toothpicks, rubber bands, bubble wrappings, foil, string, marbles. They may also use feathers, felt, Brillo, tongue depressors, etc. (Use larger Ziploc bags for mattress covers)

Procedure: If these children can successfully cooperate and work as an ensemble, they then can select a partner, discuss what and which bed they will design, and then choose specific materials from the assortment displayed on the tray in front of them. They place these materials into the Ziploc bag. They now have to judge whether their mattress (bed) meets the specifications needed to satisfy their specific customer.

This additional task might prove to be too demanding for young children. If they are satisfied with the mattress, and can convince some of their peers of the appropriateness of it, then indeed they have solved a problem. They should test it through -- all bears come into school during this particular exploration.

Extensions: Will the children note any correlation between weight, size, bed weight? Who will devise standards? Individuals have likes and dislikes, too.

Alternate Version:

1. Hand everyone an envelope of assorted materials. They spread out their materials on newspaper. Then they select a specific design to create. They choose the appropriate materials, devise a "passable" mattress, and stuff it into the Ziploc bag.
2. They create a "stuffed bear" --(art and needlework involved) to test their beds.
3. They create a mini-museum of Bear beds.
4. More Involved Long-Range Plan: Interdisciplinary Approach -- Woodworking, math, architecture, use of tools, designing three dimensional beds -- can utilize re-cycled wood, recycled cardboard, dowel sticks, straws, etc. Children submit drawings with measurements -- for younger children the measurement might be a bed that is equal to fifty paper clips in length. Children can also investigate various labels on mattresses. The school library can help by checking out those books that show how things are made, (From Tree to Table, for instance), and where things come from. Extensions might involve discussions on the different kinds of beds

used throughout the world. (It will enhance any study of multicultural focus.) There might be the added bonus of an historical perspective of furniture, its uses, design, its materials -- feather beds, cotton beds, Abraham Lincoln's straw bed in the attic, the Dutch bed, the Murphy bed, the trundle bed, hassocks, etc.

Standards-Testing: Adults will have to help the children formulate consensus on acceptable standards. Will they weigh the beds; is there a correlation between weight and firmness, weight and kinds of stuff used, firmness and stuff??

Enrichment: Those children who wish could design a bed for Goldilocks. Here is an open-ended situation where there are no restrictions or guidelines. But each child will have to explain why he/she chose the materials that he/she utilized for the execution of the design. Children could submit drawings (specifications - math/art), construct bed of wood, cardboard, etc. Another possibility is to have young children use the blocks from the block corner to design the bear's beds and/or Goldilocks' bed.

Extensions: Children can design a bed for the future -- what it can do, cannot do, will it be computerized, e.g., talking beds, folding beds, change its own sheets, adjust for weight, height?

Exploration #2 <u>Water Beds</u>

In some of my classes, we had discovered that very allergic children either had to sleep on a solid foam mattress, or adjust to a water bed, in order to prevent allergic reactions to antigens given off by common materials used in mattresses (hair).

Activity: Design a water bed which would sufficiently support a small stuffed animal brought in from home prior to lesson. Again, consensus on standards, what are standards?, who decides these regulations?, who enforces these regulations?

Materials: Small or large Ziploc bags, waterproof tape, water. Small children might like to color their water with food coloring. This is a popular activity with young children who should have had experience mixing things with water, and also discovering properties of water, properties of hot water vs. cold water, etc.

Procedure: Again, we urge that children work together, collaborate on the design of their water bed, test it with the stuffed animals. It might help if the children, using water-proof tape, fasten several Ziploc bags together to gain a bigger area. If the adults have the children outline the stuffed animal, and cut the area out, the children will begin to conceptualize the area of the water bed necessary to support their animals.

Extensions: Discussion - Pros and Cons of water beds.
Possible follow-up on solids, liquids, gases
Mini-museum of water beds

Exploration #3

Can you design an air mattress, or air bed, to support your stuffed animal, an individual in your class?

Materials: Balloons, Ziploc bags, plastic soda bottles. Children will have to fill these containers with air, which will involve lots of discussion on air. A pump that fills bicycle tires might be kept in the classroom, and sometimes you can rent the kind of pump that is used to fill helium balloons (or regular air-filled balloons). Again, taping various Ziploc bags together helps to create a larger surface area, and most probably a small child could indeed be supported by it just the way he/she is supported in a lake on an air-filled rubber raft or plastic tube.

Extension: Is it possible to devise a formula that would solve how many air Ziploc bags are needed to support an individual of a specific weight? New designs may emerge from old designs -- inner tube and otherwise!

Discussion: Emergent Problems
a. sharp instruments
b. faulty coverings
c. uneven distribution
d. allergies
e. positive points - ease in handling, uses renewable items

Enrichment: a. visit a mattress store, a department store to see types of beds
b. label beds -- practice in reading

labels on mattresses
c. health hazards
d. sanitary standards
e. individual taste -- soft beds, hard beds, etc.

Exploration #4

These children will need to have substantial interactions and experiences with materials re: strengths and weaknesses -- which materials prove stronger, weaker, which can support more weight, etc. After extensive activities in this realm, they are ready to embark on a journey which has continuously proven to be a great deal of fun for and with young children.

Connecting and linking "science" to other disciplines is crucial to setting the proper tone, foundations and attitude necessary for achieving success in science and in other disciplines -- science pervades and intrudes everywhere -- cosmetics, toys, dyes, clothes, food, etc. Why not link it up at the beginning stages of young children's education?

For instance, pre-kindergarten children are certainly conversant with The Three Little Pigs tale, yet do they discuss why each pig chose a specific material in order to construct his home? Do they brainstorm how the first little pig could have made his straw house stronger? Would a breeze or strong wind be needed to knock or blow down the house of wood? Could the wolf really blow down their houses? The opportunities are endless -- compare the pig's wooden house with a wooden house built by the settlers -- the American log cabin. Are those materials used today, where, why?

Activity:

Bring in hay (straw), scraps of wood, real bricks for children to work with. Make sure they engage in hands-on activities with these specific materials and observe each one's unique properties -- weight, texture, smell, malleable, changes in water. Again, documentation (I like to use white kitchen shelf paper for them to draw their observations, and for me to write down their thoughts and concepts. We date everything. In this way, we have established our own textbook along a continuum. We can refer back to the work we had previously studied.)

Divide the group into thirds. Each group will be given materials to construct The Straw House, The Wooden House, and the Brick House. These houses will be utilized in a class dramatization of The Three Little Pigs.

I suggest that the teacher work with each of these groups at separate times, in order to facilitate and shore up their undertakings. They definitely will need lessons on foundations and structure -- I have used dowel sticks, straws and wires, wire

hangers, rolled up newspapers, wooden scraps and clay as excellent supports.

We assume that the children have had investigations where they have classified building materials (original exploration is based on comparing, labeling and classifying various materials such as paper plates, metal pie tins, glass plates, wooden plates, plastic plates, straws, wooden blocks, Lego, cardboard, Tinker Toys, wire, toothpicks, washers, paper clips, marbles, tongue depressors, cans, coffee stirring sticks, dominoes, torn paper, keys, foil, tissue paper, wax paper, bubble paper, styrofoam, nuts and bolts, etc.) If they need additional reinforcements, they can sort through these materials to compare properties and reactions.

Questions such as: Do all the materials bend in the same way? How can you bend cardboard and foil so that they hold their shape? Did any of the materials break when they were bent?

Children should repeat the previous investigations with the other materials at hand -- straw, wooden scraps, bricks. Again document by drawings, statements, tape-recording conversations, all of their work. Photographs and video tapes are wonderful media to use if you are able to obtain cameras.

Additional Lesson:

Exploring structures and their supports. Certainly young children use clay, sand, mud, blocks, boxes, cartons. I prefer collecting and saving cardboard paper towel rollers, for young children can blow down these rollers easily. <u>But</u> then when they fill the containers with sand or mud and then blow on it, they discover that the roller still stands.

Children should be permitted to come up with optional solutions -- perhaps adding supports around the cardboard roller would also secure it. How about trying to set it in glue, in clay, in mud, into a heavier structure?

Challenge the children to make two straw houses -- one which would be blown down easily, and one which can withstand the wind without buckling under. (Adults can monitor an electric fan; an electric hair dryer can also be used.)

Follow the same format for the wooden houses -- two of them should be constructed, one which cannot withstand a wind, and one which could. (Children can apply their knowledge and understanding of concepts of weak, strong, supports, foundations to the concrete problem at hand.)

The same format can be followed with the bricks -- permit

children open explorations and they may come up with various ways to build a brick wall. (Most builders are eager to help out schools, often donating seconds or rejected bricks to schools.) Note how children aligned the rows of bricks. Math lessons as to sides of the brick, shape, corners, weight, texture, what it is made of can easily arise from this exploration. Children should document their work with journals, experience charts, drawings, photographs, videos, signs, etc.

Children can invite other grades into their classroom to view all the structures.

Questions:

a. What are the houses made of?
b. How are they different?
c. Which houses are made with the strongest materials?
d. Where do the materials come from?
e. Which houses are the weakest?
f. Why?

Children will need to work for quite awhile to strengthen their houses, and to test them. The adults have to be willing to permit a portion of the room set aside for the explorations (straw and scraps of wood (twigs) are messy - you might want to place a plastic sheet on the floor first, with brown construction paper taped over it on the floor.)

Extensions:

Comparison to the homes they live in. Vocabulary enrichment: quarry marble, natural or artificial structure, design architect, plans, foundation, substructure, skyscraper, homes in the future.

Enrichment:

a. Visit a building site
b. Make a booklet of equipment - drawings and labels
c. How does water, electricity and gas come to homes?
d. Study of houses:
    1. Cliff dwellers
    2. Sod houses
    3. Hay and bamboo houses
    4. Brownstones
    5. Castles
    6. Pueblos
    7. Tepees
e. Effect of climate and weather on houses
f. Earthquakes, tornadoes
g. Rains and drought in areas

h. Fireproofing houses
i. Inspections, rules, standards
j. Books and movies

Books such as: From Tree to Table
From Cement to Bridge
From Here to There

Children may design their own sequence of events, keeping a class log on their own creations and designs. Again, using literature such as The Three Billy Goats Gruff can inspire the children to construct bridges out of different materials. They can test them as to how much weight they can support, and also come up with their own designs. Materials, form, structure, are concepts which are utilized and applied in another context and thus reinforce their prior knowledge.

The spin-off from these kinds of lessons are far reaching. The adults can point out solar homes, energy efficient homes, recycled homes. The teacher also would have to discern the level of sophistication of these young children as to whether she/he can help the children understand the dwindling supply of natural resources.

It is important to show the children the kinds of homes used in the Third World, homes used by poor people (shanties, tin homes, cardboard homes - homeless here in the U.S.), homes used by affluent individuals, homes used by various cultures without politicizing the lesson. Children can discuss many issues if they are presented in a straightforward manner, and if they are geared to their developmental level.

The following pages involve a detailed variation on a mini-unit previously discussed in this article, namely, the houses built by The Three Little Pigs. Just as young children have to learn that the way we explain or do things today may change tomorrow, so too, did I have to reflect on my own presentations and the challenges presented to me by teachers who wish to adapt this activity to the learning styles of their children, as well as to their own teaching styles. My goal, thus, was to look at this activity a bit differently, and to suggest alternate strategies, such as six working groups, to detail in depth all that went on, and to provide a vehicle for the individual teacher to feel a sense of mastery and pride about the materials she/he brings to the world of young children.

Procedure:

I Bring into the classroom straw, scraps of wood, small bricks. Children often can supply most of the required items. Be sure to ascertain whether these children

have had explorations with the specific materials, e.g., weight, texture, malleability, unique features, origins, etc. If not, they must establish a foundation of generalizations by first experimenting with the above. Document their findings. I like to use white kitchen shelf paper for this sort of thing. We date everything. Basically, we are writing our own textbook. I, too, keep a journal and take photographs of the children at work.

II We read The Three Little Pigs aloud. We discuss why each pig chose the building material it did. We brainstorm about the house it built, its good features, its poor features, and what we could do to improve it. One child suggested concrete pilings covered with straw would be a far better structure - "pilings like those used in bridges," said he. We wondered -- in view of the interest in the recent hurricane damage -- how strong a wind need be to knock down this house, and the other pig's houses.

"Could a wolf really blow their houses in?" queried a five-year old. The opportunities presented themselves and the children were ready to test their theories and ideas. Again, utilizing shelf paper, we created our own form of documentation.

The Pigs Built...	We think that...	We tried...	We found...
A house of: straw	It needs to be: stronger	We filled: toilet paper rollers with sand and glued straw onto them. We used a hand blower to create a wind and...	The straw house: built with sand rollers was stronger than the pig's house built of straw

We also wrote and illustrated a new vocabulary book containing these new words: Foundation,

structure, materials, concrete, stone, marble, wood, basement, architect, blueprint, girders, steel, building code, supports.

Method:

I Children signed up to be the pig builders or the builders who are altering the original design of The Three Little Pigs. We basically formed six working groups of children.

Materials Needed:

Wires, wire hangers, rolled up newspapers, tongue depressors, dowel sticks, straws, brass fasteners, Scotch Tape, glue, twine, wooden scraps, Popsicle sticks, styrofoam, toothpicks, an electric fan, a hair dryer (blow dryer).

Procedures:

II We talked about plans, blueprints, how architects and builders make drawings. We brought in plans for children to view. We encouraged them to brainstorm within their designated groups and collectively come up with plans. Even the group who are acting as the pig builders should be encouraged to submit their building plans. (If I were working with older children, I might assign a particular task to each member of the group -- one the architect, one the supplier of materials, one the builder, etc. However, I learned that young children must go through some developmental milestones before they are ready for cooperative interactions.)

The six groups thus will:

Central Group (Pigs)	Other Groups
1. Construct a straw house	1. Construct an altered straw house
2. Construct a wooden house	2. Construct an altered wooden house
3. Construct a brick house	3. Construct an altered brick house

Open-ended questions often came up for further explorations and discussions. How are the houses different? Where did these materials come from? Which house is the strongest? Are the houses fireproof? Are the houses warm? What will a heavy rain do to these houses? Do people still

use straw houses? Do people still use straw houses? What happens when all the trees are used up? How do we make bricks?

Some of the outcomes:

A six-year old collected cigar boxes from his grandfather. He nailed them together, glued tongue depressors over them and then surrounded the structure by a fence of real bricks. He said his group felt that this would make a very strong wooden house. His group (with the assistance of the adults in the room) would see if it remains standing after a wind created by a fan is directed forcibly at this house.

In another science class, some five-year olds brought in empty wine cardboard cartons, taped them together, glued straw on them, set them down on the floor, anchoring each corner with wooden blocks.

After several working periods, each group had its structure in place. We video-taped the proceedings.

- Each group discussed how they constructed their building
- Some children made construction paper fans - they fanned the buildings and documented their observations
- Some children utilized the blow dryer and directed it against each structure. Again, the children documented their observations
- They also tested an electric fan's wind current effect on these structures, and also documented the results of these experiments.
- Some children suggested that we bring these structures outdoors and test them -- another option

Caution: Only adults work the electrical equipment.

Charts were placed on the chalkboards and/or easels so the children could practice predicting the outcomes. The documentation we used looked like this:

<u>We Think:</u>	<u>We Saw:</u>

Extensions and enrichment activities were planned as follow-ups. We showed videos of roads and buildings being built. We read stories like Virginia Burton's The Little House.

We went on excursions to building sites. We interviewed architects. We cut up magazines for a collage of assorted structures. We surveyed our grandparents as to what kinds of buildings they lived in. We projected into the future and created new original structures. We planned a hotel colony on the planet Mars. We began to study other peoples and the dwellings they lived in. We began to focus on animals and their houses -- which animal is an architect, e.g., beehive, wasp nest, beaver dam, oriole nest, etc. We discussed homeless individuals sleeping in refrigerator cartons, in tents, etc.

We surveyed our community for the oldest structure, the newest structure, the most common structure. We compiled data on the materials most commonly used to build these structures. We brainstormed as to why these materials were selected. We made our own bricks, and did some hands-on activities designing walls and fences. (These can also be done with wooden blocks.)

We added many new words to our vocabulary book -- rural, country, city, urban, shopping mall, neighborhood, environment, artificial, natural, etc.

We visited museums to discover how Alexander Caulder used recycled materials to fashion new items, how Frank Gehrey made furniture out of cardboard.

Thus, the children can and will become real problem-solvers if they are given the impetus to do so. Questions such as, "Do you think we should put windows on this side of the house if....," or, "I wonder what would happen if we....," are not only challenging, but are testable in hands-on activities, which are the underpinnings of a young child's search for understanding.

Bernice Hauser | Horace Mann-Barnard School

SCIENCE

Recommended Resources for Young Children

A.	Nature Scope Series (15 books) Animals, Weather, Deserts Turtles and Frogs, Birds, Oceans, Rainforests, Geology, Trees, etc., etc.	National Wildlife Federation 1412 16th Street, N.W. Washington, DC 20036-2266 Single copies $6. 15 - Series $79. ($3.50 shipping)
B.	Publications	
	Your Big Backyard - $10 yearly Ranger Rick - $14 yearly	National Wildlife Federation (Same as above)
C.	1. Science Fun with Toy Boats and Planes 2. Science Fun with Peanuts and Popcorn 3. Science Fun with Mud and Sand 4. Science Fun with Homemade Chemistry Set 5. Science Fun with Cars and Trains	by Rose Wyler Published by: Julian Messner Div. of Simon & Schuster 1230 Avenue of the Americas New York, NY 10020 (about $5 each)
D.	Take One Balloon Take One Straw Take One Magnifying Glass Take One Mirror	Melvin Berger, Scholastic Press, Inc., New York, NY
E.	Early Childhood and Science ($7.50)	Margaret McIntyre National Science Teachers Association 1742 Connecticut Avenue, N.W. Washington, DC 20009
F.	Lady Bird Series Animals, Magnets, Air, Leaves, Birds, Living Things, etc., etc.	Leicestershire Learning Systems Lewiston, ME 04240 or Barnes and Nobles 18th Street New York, NY
	Brown Paper Bag Series Blood and Guts Beastly Neighbors Make Mine Music (etc., etc., etc.)	Little, Brown and Company Boston, MA

G.	<u>Windows on Science Series</u> 1. Water and Ice 2. Insects and Other Crawlers 3. Light, Color, Shadows 4. Rocks, Sand and Soil 5. Seeds and Weeds 6. Constructions (Management Guide optional)	Creative Publications 788 Palomar Avenue Sunnyvale, CA 94086 (Cat. #56920)

Early Childhood - Second Grade

H.	From Tree to Table From Cement to Bridge From Here to There	Ali Mitgutsch Carolrhoda Books, Inc. Minneapolis, MN
I.	The Little House	Virginia Burton Houghton-Mifflin New York, NY

"IF YOU WANT TO TEACH SCIENCE, START WITH TECHNOLOGY"

By
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Technology is a new subject area in the schools today. In most countries in the world, technology is less than a decade old, thus it is still in the developmental process. With the evolution of the discipline called technology, there naturally are some different opinions on what it is and where it should be taught. Some view technology as a part of science curriculum, while others think that it is more closely allied with engineering. Some countries, such as Germany, place technology as a component of vocational education. Others believe that technology should be taught in an integrative manner with mathematics, science, social studies and other subjects (the science, technology, society - STS- movement is a good example of this).

What should be the relationship between science, engineering and technology in education in the future? How should future citizens be best educated to live in an increasingly more complex technological world?

The publication "America's Academic Future", a report of the National Science Foundation Presidential Young Investigator Colloquium on U.S. Engineering, Mathematics and Science Education for the Year 2000 and Beyond, presented our society in the next decade as:

> *...a society in which the public regards science, mathematics and technology as relevant to their personal lives. Engineers, mathematicians, and scientists are perceived by the public as vital to society, and scientific and technological literacy* are *well defined. Engineering, mathematics, and science concepts and contributions are communicated effectively to all segments of society, principally through formal instruction in our schools and universities but also through informal out-of-class educational opportunities and programs. The public can apply the principles of science to the solution of their everyday problems.*